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THE MORPHOLOGY OF DINOPHILUS CONKLINI n. sp.

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I. INTRODUCTION.

The systematic position of *Dinophilus* has been a subject of considerable interest to naturalists ever since the establishment of the genus by Oscar Schmidt in 1848, and the opinions held on this point have been—relatively speaking—many and various. In a former paper on the early development of this form (1904*a*) I gave a brief review of these; to repeat it here seems superfluous. In the paper just mentioned certain conclusions as to the relationships of *Dinophilus* were stated, based on a study of its development. In the studies of which the present paper is the result, an attempt has been made to test these conclusions by a study at first hand of the morphology of the same species. This seemed the more desirable, since in the last fifteen years there have appeared but three papers on the structure of members of this group, and those dealt with species different in many respects from the one studied by me. Moreover, the apparent rarity of *Dinophilus* and its sporadic occurrence was an additional incentive to making the best of the opportunity which presented itself in finding abundant material for the study of its morphology, as well as its development, in the aquaria of the University of Pennsylvania.

It gives me pleasure to take this opportunity to express my indebtedness to Prof. E. G. Conklin, of the University of Pennsylvania, for the privilege of taking *Dinophilus* material from the aquaria of the University; to the Carnegie Institution for the use of one of its rooms at Woods

Hole during the summer of 1903; and to Prof. L. B. Walton for extending to me the use of the biological laboratory at Kenyon College. I wish especially to thank Prof. J. H. Comstock for the unfailing kindness he has shown me at Cornell University. I wish also to thank my friends, Dr. J. Percy Moore, of the University of Pennsylvania, and Prof. A. D. MacGillivray, of Cornell University, for kindly advice and criticism.

II. Material and Technique.

All of the material employed in the preparation of this paper was obtained from the sea-water aquaria of the University of Pennsylvania. This material was collected in three lots at three different periods. The first lot was taken during the winter of 1901–2, and its preservation was only incidental to the collection of ova, which formed the basis of a former paper by me (1904) on the early embryology of this form. The individuals taken at this time were among the largest obtained. The second lot was taken during the latter part of June and the first few days of July, 1903. These individuals averaged possibly one-fourth to one-third smaller than those of the first lot. The third lot was obtained during the winter of 1903–4. The individuals comprised in this lot are intermediate in size between those of the first two lots, being much larger than those of the second lot, but scarcely equalling those of the first.

The methods of fixation employed were but three in number:

(1) Kleinenberg's picro-sulphuric for one-half to three-quarters of an hour, followed by a washing in 70 per cent. alcohol. This method of fixation, which has given excellent results for many ova, including those of this form, proved only an indifferent one for the mature individuals, and material fixed in this manner was unsuitable for the study of any of the finer structures. It has, however, the advantage of preserving the form and proportions of the object very well, and this material was made use of largely as mounted entire.

(2) A saturated aqueous solution of corrosive sublimate, containing 6 per cent. of glacial acetic acid, used boiling hot, and followed by a thorough washing in 70 per cent. alcohol. The material fixed in this manner has proved exceedingly valuable, and many of my best drawings were made from it. The form and relation of the different parts are admirably preserved, as well as those of the cells composing them, while in many cases the finer structures, such as cilia, maintain their integrity. After sectioning and staining the individuals collected in the summer of 1903, which were fixed by this method, a peculiar

differentiation of the nerve fibres became evident. The latter did not absorb the chromatin stain (iron-hæmatoxylin), but on the contrary remained clear and of a light straw yellow color, or, in sections where eosin was used as a contrast stain, were pale orange. In either case the nerve fibres are easily distinguished from the surrounding tissues. What happy accident caused this differentiation, which occurs in all the series made from the second lot of individuals, I have not been able to determine. It has, however, been of the highest value to me, since without its assistance it would have been an extremely difficult matter to trace out the various parts of the nervous system. That it is but an accident I feel sure, since a number of individuals of another lot, fixed and stained by the same method, showed the nerve fibres stained dark gray, as is the case where other fixatives were used.

(3) Flemming's fluid, from one-half to twenty-four hours. This method gave very irregular results, yielding some of the finest preparations, as well as some of the poorest. Different individuals, even of the same lot, vary much in the quality of the fixation. The best results were obtained with a fixation of half an hour, although the period of fixation seems to be of minor consequence, since good results were also obtained with a fixation period as long as twenty-four hours.

The stains employed were: the picro-hæmatoxylin of Conklin (1902) for the objects mounted entire, and Haidenhein's iron-hæmatoxylin for sections. A contrast stain was used in some cases, a saturated aqueous solution of eosin being employed for this purpose. Experience, however, has shown that the use of a plasma stain with the iron-hæmatoxylin is, in this form at least, unnecessary, if not actually undesirable. For the purpose of determining the presence of mucin in the hypodermis, Mayer's mucicarmine was employed. The formula is that given by Lee in the fifth edition of *The Microtomist's Vade-Mecum*, the material being stained from five to fifteen minutes in a 10 per cent. solution.

The sections were for the most part cut five μ in thickness, this being found to be the minimum compatible with perfect series. Many of the *Dinophilus* were embedded and oriented separately, but the best horizontal and sagittal series were obtained by embedding a large number in a Lefevre watch glass, and sectioning the mass entire.

The living animals were also studied, but, on account of the refractive nature of the protoplasm, proved very unfavorable objects, as far as the internal structure was concerned. Narcotization was successfully accomplished by the use of chlorotone, the animals soon becoming quiescent, in a relaxed condition, lying on one side, with a slight ventral flexure.

The small size of the cells of this species of *Dinophilus*, and the general lack of distinctness in the boundaries of tissues and organs, made imperative the use of the highest powers. In studying and drawing sections a one-twelfth Zeiss oil immersion was employed almost exclusively. This necessitated a brilliant illumination. After the loss of much time from cloudy and dark weather, I had recourse to artificial illumination, as recommended by Child (1900). For this purpose I used a burner of the Welsbach type, mounted about nine inches above the table. Two blue glasses were placed in the cell below the condenser, one dense and one thin. I heartily concur with Child in the opinion that this means of illumination is superior to daylight, at least when high powers are employed. The light, when filtered through the blue glasses, is almost perfectly white, does not tire the eyes, is of constant and unvarying intensity, and, above all, is always available.

In making the reconstructions which constitute Plate XII, fig. 1 and text fig. IV, a modification of the method given by Lee (*Microtomist's Vade-Mecum*, 5th ed., 1900) and ascribed to Woodworth, was employed. The camera lucida was, however, used in place of a micrometer. Such reconstructions proved of the greatest value in determining the relations and connections of parts which run through a number of sections.

III. ANATOMY.

1. *External Form and Specific Characters of Dinophilus conklini.*

The *Dinophilus* which forms the subject of this paper has been found, after comparison with the descriptions of the other members of this genus, sufficiently different from them to warrant description as a new species. I take great pleasure in bestowing upon it the specific name *conklini*, in honor of Prof. E. G. Conklin, of the University of Pennsylvania, who was the first to find this form. This species has so far been found only in the aquaria belonging to the University of Pennsylvania. Prof. Conklin, however, informs me that he is of the opinion that it is brought in on the *Ulva* obtained by dredging at Sea Isle City, New Jersey. A comparison with other species and the enumeration of specific characters are postponed to the end of this section.

The females of *Dinophilus conklini* are very wormlike in their form and general aspect. Text fig. I, although drawn from a fixed and stained preparation, shows little or no distortion, and represents the animal in a state of moderate extension, such as it often naturally

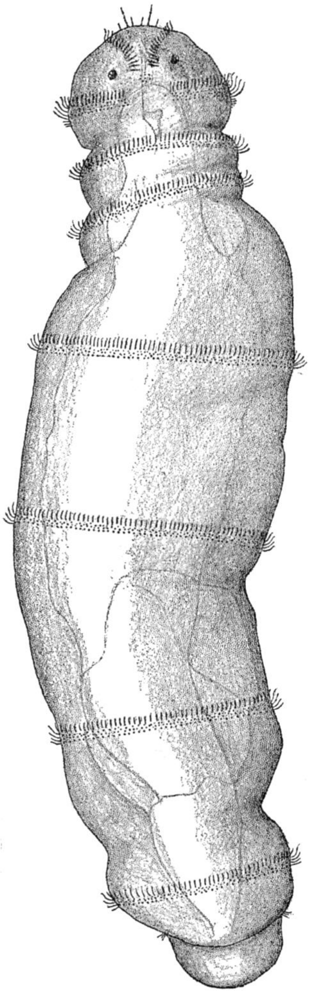

Fig. I.—Female individual of *D. conklini,* drawn from a fixed and mounted specimen. Details added from sketches of living animals. (× 142.)

assumes in crawling about over the seaweeds on which it is commonly found. The outlines of the example from which fig. 1, Pl. XII, was taken represent the animal in a somewhat greater state of extension, showing especially well the form of the last segment and the caudal appendage. The head is bluntly conical or rounded in front, and narrows posteriorly to a somewhat constricted neck, where it joins the trunk. Its dorsal surface is also rounded, and bears a pair of reddish eyes, reniform in shape, as is usual in this group. On its ventral surface the head is slightly flattened. The trunk is long fusiform, or cigar-shaped, tapering toward the posterior end, and divided by six constrictions into as many segments.[1] The first two segments are very short, scarcely equal to the head in diameter and are limited by relatively deep and well-marked constrictions. The three succeeding segments are subequal, nearly as broad as long, and separated by comparatively slight constrictions. In the first of the segments last described, namely, the third of the trunk, the latter reaches its greatest diameter. The sixth segment is short and rounded at its posterior end, and bears on its ventro-posterior surface the conical caudal appendage or tail, which in this species is unsegmented.

Like other members of the group, *D. conklini* is encircled by a number of bands or rings of cilia, and also possesses the usual ciliated tracts on the ventral surface. One of the latter, the preoral tract, clothes the ventral surface of the head, and at its posterior margin passes into the ciliated lining of the mouth. It serves the obvious purpose of creating currents of water which sweep particles of food toward and into the mouth. The second or postoral tract comprises a narrow strip beginning at the posterior border of the mouth and continued backward to the end of the caudal appendage. This strip is widest in its anterior portion, having here a width of approximately one-half of the diameter of the body. From this point it narrows posteriorly and is reduced to a third of its original width on reaching the caudal appendage.

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[1] In the descriptive portion of this paper the term "segment" will be used to designate a portion of the trunk bounded by constrictions, without reference to the question whether it is a true metamere. The problem of metamerism in *Dinophilus* is discussed in Section III, 7.

The ciliated rings number nine; two belonging to the head and seven to the trunk. The two cephalic bands are not, however, continuous, each being interrupted on the middorsal surface of the head by a considerable gap; both of the two rings are thus divided, with the aid of the ventral ciliated tract, into two lateral halves. The two bands composing the first ring arise on the ventral surface, at the lateral edges of the ciliated tract, a short distance posterior to the anterior pole of the head; they then pass upwards and backwards in a gentle curve, and terminate between the eyes (see text fig. I). These bands are narrow, and composed of but few rows of cilia. The two bands representing the second cephalic ring embrace the head at its greatest diameter, and lie in a plane at right angles to the long axis of the animal. These bands are relatively broad and composed of numerous rows of long cilia. As is the case with all the ciliated rings the cilia beat rhythmically backwards, and are only clearly seen in their forward position, that of recoil.

In the first preoral or cephalic band of *D. vorticoides*, as described by Schimkewitsch (1895), there is a similar gap. It is possible that in other species of *Dinophilus* the cephalic bands are also not continuous dorsally, since the cilia are here not easy to make out, except when the animal is seen in profile, or by the study of sections of fixed and stained material. In the case of this species I was at first misled as to the course of the cephalic bands and figured them incorrectly (1904*a*, text fig. VI). This misapprehension was due to the figures and descriptions of other species, and also to the presence of sensory cilia on the dorsal surface of the head, as described below.

The discovery of the presence of a dorsal gap in the second cephalic ring was of particular interest to me, inasmuch as it tends strongly to confirm my conclusions as to the origin of this band and its homology with the prototroch of the trochophore larva, as expressed in 1904.

In the embryo of *Dinophilus*, the "trochoblasts," the cells which presumably form this ring, are last seen as a long band, continuous across the ventral surface, but interrupted dorsally by a wide gap. A similar gap is also present in the prototroch of some annelid larvæ, as, for example, in *Amphitrite* (Mead, 1897), and due to the same cause as in *Dinophilus*, namely, the large size of 2d (X), "the first somatoblast" of von Wistinghausen (1891), and the rapid growth of its dorsal products. This dorsal gap is eventually closed in the case of *Amphitrite*, but it is in this form much narrower than in *Dinophilus;* the cells composing the prototroch are relatively large, and soon become functional. It appears quite probable, therefore, that the dorsal gap seen in the second cephalic band of the mature *Dinophilus* is ultimately traceable to the peculiar size-relation and growth processes of the cleavage cells of the ovum of this species.

Just behind the second cephalic band is a pair of shallow grooves, which arise high up on the sides of the head and pass ventrad, widening and deepening slightly, to join the mouth at its lateral margins. These grooves are lined with short cilia throughout their extent. These are the "Wimpergruben" observed by Schmidt (1848) in *D. vorticoides*, by Hallez (1879) in *D. metameroides*, and by Korschelt (1882) in *D. apatris*. They are supposed by the authors mentioned to function as sense organs, but their relation to the mouth seems to indicate that they may also act as food-gathering organs, creating currents which sweep the food particles down into the mouth. It may be remarked in passing that the "Wimpergruben" of this species of *Dinophilus* are strikingly similar to the ciliated grooves of *Ælosoma tenebrarum,* as described by Miss Brace (1901).

The seven ciliated bands of the trunk are simple narrow transverse circlets, uninterrupted on the dorsal surface, with the exception of the last. Below they merge with the ventral ciliated strip. Each band encircles the middle of its respective segment. The terminal or circumanal ring is scarcely worthy of the name, since it consists only of two short ciliated bands. These arise at edges of the ventral ciliated area, at the point where the last segment joins the caudal appendage, and pass upward on the posterior edges of the segment for a short distance (see text fig. I).

In common with other species of this group, *D. conklini* possesses conspicuous sense hairs on the anterior surface of the head. Two of these are of considerable size and symmetrically placed, pointing forward and slightly outward, while scattered between and around them are a number of smaller hairs. These are in fact tapering projections of naked protoplasm; the large sense hairs, as Korschelt (1882) has observed, are capable of movement. This movement consists in a gentle waving to and fro of the tips, especially noticeable when these cilia come into contact with foreign objects, and demonstrating clearly their tactile function. On the dorsal surface of the head, just behind the eyes, is another group of sense hairs, all of which are very small.

Like both *D. gyrociliatus* and *apatris*, which it closely resembles in other respects, *D. conklini* is colorless. Although lacking in color, it is relatively opaque; this quality appearing to be due to the refractive qualities of the protoplasm, rather than to anything contained within the body of the animal. When seen by reflected light its shining opaque whiteness makes it a conspicuous object when viewed against the dark background formed by the seaweeds on which it is commonly found. This lack of transparency naturally renders more difficult the study of the internal structure of the living animal.

The size of this species is subject to great variation. Measurements of the length of adult examples (in alcohol) of the first lot, taken in the winter of 1901–2, vary from 0.57 mm. to 0.91 mm.; the average of this lot being about 0.73 mm. This variation in length is doubtless in part due to the differing degree of contraction of the examples taken, but it also, to a considerable extent, represents a real variation in size. Fully extended living individuals would yield measurements possibly one-tenth to one-fifth greater, but it is doubtful if any would exceed 1 mm. The examples of the second or summer lot, although less contracted by the fixing fluid than those of the first, show a range of 0.309 mm. to 0.60 mm., the average length being only 0.46 mm. From the third lot (winter 1903–4) only a few measurements were taken. The maximum of these was 0.74 mm., while the average was 0.616 mm. From these measurements it seems to follow that summer individuals are much smaller than those taken in cold weather. This may really be the case, but unfortunately these observations are not extensive enough to form the basis of any certain conclusions regarding this matter. All the examples taken were, or appeared to be, sexually mature. Considerable variation in size has also been noted by Korschelt (1882) in *D. apatris*, and by Weldon (1886) in *D. gigas*. The first mentioned author says, "Seine Länge ist bei geschlechtsreife Thiere ziemlich verschieden." Weldon states that "The length of the body varied greatly, the smallest specimens found being about 0.75 mm., while the largest were nearly two millimeters in length." Whether all these were sexually mature is not stated.

Of the males of this species, only one was observed. This was still confined in the egg capsule, together with female embryos, but was nevertheless fully formed and swimming about as freely as its limited quarters would allow. In all essential characters it resembles the male of *D. apatris* Korsch. Its form (text figs. II, A and B) is that of a short cylinder with rounded ends, slightly constricted at its middle. About the anterior end is a ring of cilia situated in a groove. This ring is continuous below with a strip of cilia clothing the ventral surface. At its posterior end was seen the outlines of the conical penis, which is directed downward and backward, as Korschelt (1882, 1889) has figured it. Of the interior of the body little else could be discerned except a number of refractive granules, which were probably spermatozoa.

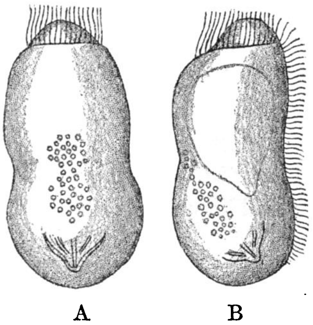
A B

Fig. II.—Male individual of *D. conklini*, drawn from a living specimen. A, dorsal surface ; B, lateral surface.

As will appear from a glance at the table of species given below, *D. conklini* stands very close to *D. apatris* Korsch. and *D. gyrociliatus* O. Sch. From *D. apatris* it differs in the proportions of head and trunk, in the presence of dorsal gaps in the preoral ciliated bands, in having but two large sense hairs instead of four, and in the presence of a cicumanal or terminal band. *D. conklini* moreover lacks a character which seems to be distinctive of *D. apatris*, namely, that of having the head joined to the trunk by the intermediation of a short piece, which has the appearance of a much shortened segment, without the ring of cilia. The characters distinguishing *D. gyrociliatus* and *D. conklini* are much slighter. Indeed the sole external difference distinguishing the two species is the presence of the dorsal gaps in the two preoral bands of cilia in *D. conklini*. This alone would seem far too slender a basis on which to erect a new species, if it were not that it is accompanied by considerable differences in the internal organs, the nephridia in particular.

In the table below an attempt has been made to set forth in brief form the distinguishing characters of the different species composing the group, and the literature directly relating to each. That this table is imperfect is certain, but this is due at least in part to the imperfectness of many of the descriptions, especially the earlier ones. Later descriptions and figures, when such exist, have been used in the belief that they are more likely to be accurate. The literature list is as accurate and complete as lay in the writer's power to make it, but it has been found wellnigh impossible to collect all of the scattered references to the genus. If either the table of species or the literature list proves helpful to any student of the group, or serves to faciliate comparison of the characters of the various species, it will have fulfilled its purpose. The characterization of the genus has been added for the sake of completeness.

Genus **DINOPHILUS.**

Minute wormlike forms, generally displaying an external division into segments, delimited by constrictions; each trunk segment, including the head, bearing one or two bands or circlets of long cilia; in addition to these a ciliated strip clothes the ventral surface. The last segment bears a conical caudal appendage. The anterior surface of the head usually provided with sense hairs. Alimentary canal well developed (except in the degenerate males of certain species), consisting of a mouth opening on the ventral surface of the head; an œsophagus provided on its posterior inner surface, where it joins the mouth, with an eversible proboscis; a capacious stomach, and a short intestine terminating dorsad to the caudal appendage. Cœlom represented by the cavities of the gonads. A primary body cavity of varying extent always present. Nervous system consisting of a simple brain, a pair of circumœsophageal commissures, and, continuous with the latter, two ventral cords, embedded in the hypodermis. In some members of the group, at least, are also present transverse commissures and pairs of ganglia correlated with the segments as indicated on the exterior. Nephridia, when present, of the protonephridial or larval type, and arranged metamerically.

Table of Species of Dinophilus.—

- A.—Sexes monomorphic.
  - B.—Gonads paired, extending to the anterior extremity of the trunk. Two bands of cilia borne by each trunk segment.
    - C.—Trunk segments 6.
      - D.—Caudal appendage 3-segmented, ... *vorticoides.*
      - DD.—Caudal appendage unsegmented, ... *gardineri.*
    - CC.—Trunk segments 5, ... *tæniatus.*
  - BB.—Gonads Y-shaped; only one band of cilia borne on each trunk segment, ... *gigas.*

AA.—Sexes dimorphic, the males much reduced and degenerate in structure; corresponding with this condition is a dimorphism of the ova. Ovary unpaired. Only one band of cilia borne on each trunk segment, with the exception of the last, which may bear two.
  B.—Trunk segments 6.
    C.—Body not covered with a coat of cilia between the bands.
      D.—Circumanal band present.
        E.—Cephalic bands without dorsal interruptions; anterior pair of nephridia simple, . . . *gyrociliatus.*
        EE.—Cephalic bands with dorsal interruptions; anterior pair of nephridia complex, ... *conklini.*
      DD.—Circumanal band wanting, ... *apatris.*
    CC.—Body covered with a coat of cilia between the bands, *metameroides.*[2]
  BB.—Trunk segments 5, ... *pygmæus.*

List of Species of Dinophilus.—

1. **Dinophilus vorticoides.**[3]

Schmidt, 1848.—Schultze, 1849.—Diesing, 1850.—Beneden, 1851.—Quatrefages, 1851.—Beneden, 1861.—Diesing, 1862.—Graff, 1882.—Weldon, 1886.—Harmer, 1889a.—Schimkewitsch, 1895.—Schultz, 1902.

Head equal in width to first trunk segment, bearing two ciliated bands; the first with a dorsal gap (Schimkewitsch), the second uninterrupted. Ovaries four-lobed. Color, orange. Length, (?). Habitat, Faroe Islands (Schmidt), Belgian coast (Beneden), White Sea (Mereschkowsky, Schimkewitsch).

2. **Dinophilus gardineri.**

Moore, 1899.—Schultz, 1902.

Head not wider than first trunk segment, bearing two ciliated bands(?). Body covered with a coat of cilia in addition to the ciliated bands. Caudal appendage short. Color, orange red. Habitat, brackish pools, Woods Hole, Massachusetts, U. S. A.

3. **Dinophilus tæniatus.**

Harmer, 1889, 1889a.—Schimkewitsch, 1895.—Schultz, 1902.—Shearer, 1906.

Head slightly narrower than first trunk segment, bearing two uninterrupted ciliated bands. Circumanal band present. Female with ovaries four-lobed, male with a median penis and lateral seminal vesicles. Color, bright orange. Length, 2.0 mm. Habitat, Plymouth, England.

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[2] That this species is dimorphic is assumed on the ground that Hallez found no males. If this assumption is correct it is probable that the ovary is unpaired.

[3] Graff (1882), following Diesing (1850), considers this species identical with *Vortex capitata* Oersted (1843) and *Goniocarena capitata* Schmarda (1859). Oersted's original description being inaccessible, it seemed advisable to allow Schmidt's name to stand provisionally.

4. Dinophilus gigas.

Weldon, 1886.—Korschelt, 1887.—Harmer, 1889a.—Schimkewitsch, 1895.—Schultz, 1902.

Head slightly wider than first trunk segment, bearing one ciliated band. Trunk segments seven. No circumanal band. Long sense hairs in two symmetrical patches on the anterior surface of the head. Color, a brilliant orange. Length, 0.75–2.0 mm. Habitat, Mounts Bay, Penzance, England.

5. Dinophilus gyrociliatus.

Schmidt, 1857.—Diesing, 1862.—Korschelt, 1882.—Meyer, 1886.—Repiachoff, 1886.—Korschelt, 1887.—Harmer, 1889a.—Schimkewitsch, 1895.—Schultz, 1902.

Head not wider than first trunk segment, bearing two complete ciliated bands. Caudal appendage unsegmented. Two large sense hairs on the anterior surface of the head symmetrically placed(?). Colorless. Length, (?). Habitat, Naples, Italy.

6. Dinophilus conklini n. sp. Pls. XII, XIII.

Head not wider than first trunk segment, bearing two ciliated bands. An imperfect circumanal band present. Caudal appendage unsegmented. Two symmetrically placed large sense hairs on the anterior surface of the head, in addition to several smaller ones. Colorless. Length, 0.50–1.0 mm. Habitat, aquaria, Philadelphia, Pa., U. S. A.; New Jersey coast, U. S. A.(?).

7. Dinophilus apatris.

Korschelt, 1882.—Repiachoff, 1886.—Harmer, 1889a.—Schimkewitsch, 1895.—Prowazek, 1900.—Schultz, 1902.—Malsen, 1906.

Head wider than any of the trunk segments, bearing two ciliated bands. Head joined to trunk by a short piece having the appearance of an imperfectly developed segment without the ciliated band. Caudal appendage unsegmented. Four very large sense hairs on the anterior surface of the head in two symmetrical pairs. Colorless. Length, 1.2 mm. Habitat, aquaria, Freiburg (Korschelt) and Berlin (Prowazek). Also found at Trieste, Austria (von Malsen).

8. Dinophilus metameroides.

Hallez, 1879.—Korschelt, 1882.—Graff, 1882.—Weldon, 1886.—Korschelt, 1887.—Harmer, 1889.—Schimkewitsch, 1895.—Schultz, 1902.

Head bearing two ciliated bands. Trunk segments sharply demarcated, the first much longer than the others. Caudal appendage 5–6 annulate with long papillæ. Mouth a longitudinal cleft. Color, red. Length, (?). Habitat, Wimereaux, France.

9. Dinophilus pygmæus.

Verrill, 1892.—Schimkewitsch, 1895.—Schultz, 1902.

Head equal in width to first trunk segment, bearing two complete ciliated bands. No circumanal band present. Caudal appendage short and unsegmented. Male unknown. Color, (?). Length, 0.7 mm. Habitat, Woods Hole, Massachusetts, U. S. A.

Unrecognized Species.—

Dinophilus sphærocephalus Schmarda, 1859. Guayaquil, S. A. Description scanty and inadequate.

Dinophilus borealis Diesing, 1862. This species is considered by Diesing to be equivalent to *Plagiostomum boreale* O. Schmidt, and *Vortex vittata* Frey and Leuckart. It is probably a true turbellarian.

Dinophilus ——— Jensen, 1878.

Dinophilus caudatus Levinson, 1879–80. Levinson, curiously enough, considers this species identical with *D. vorticoides* O. Sch., and also with *Planaria caudata* of Fabricius (*Fauna Groenlandica*) and Müller (*Zoologica Danica*). I was unable to satisfy myself that this was the case, and therefore allowed Schmidt's name to stand.

Dinophilus rostratus Schultz, 1902. This curious form is clearly not a member of the genus *Dinophilus*, whatever its relationships may be.

2. *Body Wall.*

The body wall consists of the hypodermis and the circular and longitudinal muscles. It also contains the longitudinal nerve cords, as well as sensory cells; these are described in the section on the nervous system.

The hypodermis is a simple epithelium whose cells rest internally upon a thin basement membrane, and are clothed externally by a cuticle. The body wall, generally speaking, is quite thin relative to the size of the animal, but its thickness differs much in the various parts of the body, and also varies in proportion to its degree of contraction. In the region of the head, more particularly on its ventral side, the hypodermis reaches its greatest thickness, about 15 μ. In the trunk there is a thickened portion along the ventral side,[4] roughly coincident with the ciliated area of this region; it is slightly thicker near the middle of its length than at the ends (figs. 6, 7, 8 and 9). In the

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[4] Shearer (1906) has compared this thickened area with the "crawling pad" of the *Turbellaria*. It is, however, rather to be compared to the ventral plate of annelid larvæ, since it is formed in the same manner and from the same cleavage cells (Schimkewitsch, 1895; Nelson, 1904).

posterior part of the last segment, especially on the dorsal side, the hypodermis is also much thickened. On the dorsum and sides of the trunk, however, the thickness of the body wall is closely related to the external segmentation. At the middle region of each segment the hypodermis reaches the thickness attained by its ventral portion (5–8 μ); it gradually becomes thinner toward the limits of each segment, its minimum, ca. 3 μ, being reached in the intersegmental regions. These differences in the height of the hypodermal cells find expression on the external surface of the body wall alone, which consequently in longitudinal section presents an undulating outline. In cases where the contraction of the animal has been excessive, the exterior of the body wall may even have the appearance of being deeply indented in the intersegmental regions.

Supporting Cells.—The hypodermal cells are differentiated into supporting cells, ciliated and non-ciliated, and gland cells. The non-ciliated supporting cells (fig. 14, also figs. 2–8), which make up the greater portion of the hypodermis, are simple epithelial cells, flat in the thinner portion of the body wall, but in the thicker portions becoming cuboidal and even columnar, as in some parts of the head. In the ventral portion of the latter, for example, the hypodermal cells are so closely set together that the bases of some of them seem to have been forced inward, and have the appearance of pyriform processes, each of which contains a nucleus (Pl. XIII, fig. 23). The cytoplasm of the non-ciliated cells is clear; high magnification presents an alveolar appearance. Throughout the region of the head, next to the hypodermis, is a distinct layer of vacuoles (figs. 2 and 12), similar to that described by Meyer (1901) as occurring in the larva of *Lopadorhynchus*. A layer of smaller vacuoles is also discernible in the hypodermis of the trunk (fig. 6). The nuclei are spherical or ovoid, provided with an open reticulum of linin, bearing minute chromatin granules and a large and prominent chromatin nucleolus (karyosome). The ciliated cells may, in sections, be at once distinguished by their darker aspect, and are, as described in the preceding section, distributed to form two ventral tracts and nine bands. The latter are, with the exception of the second cephalic band, composed of but one row of cells, their outer surfaces elongated in the direction of the band (fig. 27), and meeting only at their extreme ends. The second cephalic ring or band is, on the other hand, composed of two rows of cells (fig. 28, *c.r.* 2), similar to those of the other bands. This difference has also been noted by Schimkewitsch (1895) in the White Sea *Dinophilus* (*D. vorticoides*). The cells composing the cephalic bands are wedge-shaped, in conformity with the general thickness of the hypodermis of this region; the point of the wedge being directed inwards (figs. 19 and 20). The nuclei of these cells are situated near their inner ends, and often compressed laterally.

The ventral ciliated areas of the trunk and head are essentially similar in structure. That of the trunk contains both ciliated and non-ciliated cells in the proportion of about two to one (fig. 28). The outer surfaces of these cells are irregularly polyhedral and not elongated in the direction of the long axis of the body, as Schimkewitsch (1895) has described them in *D. vorticoides.* The cells composing the ventral ciliated strip are cubical or columnar near the midline, but toward the outer margin of the strip the cell walls slant inwards, so that the cells here have the form of pyramids or truncated cones, as illustrated in fig. 14.

The nuclei of the cilia-bearing cells resemble those of the non-ciliated supporting cells. The cytoplasm of the ciliated cells is also finely alveolar. Embedded in the cytoplasm, at a short distance from the cuticle, are the end knobs of the cilia. These are oval in form, separated from one another by a distance of about 1 μ. From the outer ends of these arise the cilia, which pass to the distal surface of the cell and, piercing the cuticle, reach the exterior. The inner ends of the knobs are attached to the intracellular fibrillæ usually present in cilia-bearing cells; these have the appearance, in the best preserved material, fixed in Flemming's fluid, of true fibrils, homogeneous in structure. These fibrillæ are exceedingly conspicuous in material fixed in sublimate, appearing in such preparations as tapering rods (figs, 6, 7, and 9). They pass inward to the base of the cell, and do not always converge toward the nucleus. In some cases two or more fibrillæ may be seen to join together, and finally to terminate on the basement membrane at a considerable distance from the nucleus, as seen in the middle cell in fig. 14. To these fibrillæ, which are always more or less intensely stained, the ciliated cells owe largely their darker aspect, as compared with the non-ciliated supporting cells.

The hypodermis, as already noted, is everywhere covered externally by a cuticle. The latter is refractive, nearly homogeneous, or with faint striations parallel to its surface. Its thickness ranges from ca. 0.9 μ on the ventral surface of the trunk to ca. 1.1 μ on the ventral surface of the head, where the hypodermis also reaches its maximum thickness.

Gland Cells.—The hypodermis is very rich in unicellular glands, most of which are of large size relative to that of the supporting cells. These glands are of three kinds or types; those of the first two types containing mucin, staining intensely with Mayer's mucicarmine; the nature of the secretion of those of the third type is undetermined.

The glands of the first type (fig. 15) are but few in number, and scattered irregularly over the ventral surface of the trunk. In form they are flask- or sac-shaped, with a narrow and constricted mouth. The mucus with which they are filled appears nearly homogeneous, although under a high magnification it presents, in some cases, a finely fibrillar structure. It has, however, never been observed to break up into blocks, as often happens in mucous glands, as, for example, in those of *D. vorticoides*, as described by Schimkewitsch (1895). Flattened out against the wall of the gland, and usually a little to one side of its base, is found the shrunken nucleus (*n.*), together with the dark staining and scanty remnant of the original cytoplasm. None of the glands of this type were seen in the act of discharging their contents.

The glands of the second type (fig. 16) are also mucous glands, their contents staining intensely in Delafield's hæmatoxylin, in Conklin's modification of this stain (1902) and picrocarmine, as well as in Meyer's mucicarmine. They thus become very conspicuous in examples mounted entire, when stained in any of these stains. Examination of individuals thus mounted discloses the interesting fact that these glands have, for the most part, a fairly constant and symmetrical arrangement, and, with the exception of two groups on the last segment, vary but slightly in

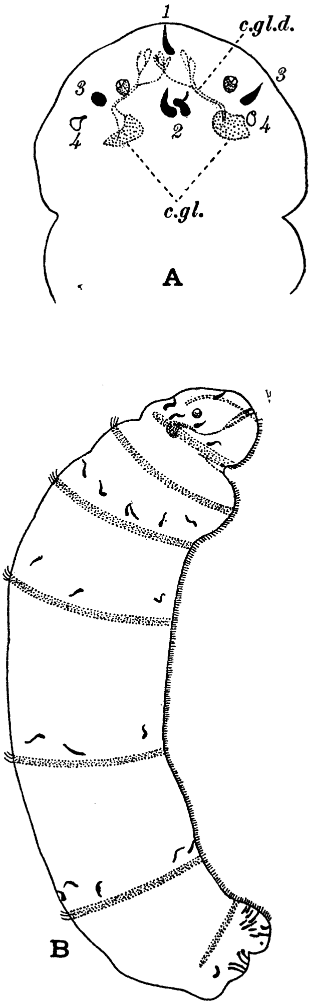

Fig. III.—Diagrams illustrating the distribution of the hypodermal mucous glands (second type), from camera drawings of fixed specimens. A, head, seen from dorsal surface. 1–4, mucous glands; *c.gl.*, cephalic glands; *c.gl.d.*, duct of cephalic gland. B, entire animal, seen in side view.

number. Their usual arrangement is that illustrated in text fig. III, A and B. As may be seen on examination of this figure, the head bears seven of these glands, one median unpaired gland near the anterior pole of the head (1), and three pairs symmetrically grouped on its anterior surface (2, 3, and 4). On the trunk their distribution is metameric as well as symmetrical, a row of these glands encircling each of the trunk segments—except the first and last—near its middle, just anterior to the ciliated bands. The second segment commonly possesses five pairs of glands, the third but three pairs, while the fourth and fifth segments have four pairs each. On the sixth segment the glands of this type are divided into two small groups, one occupying a crescentic area just above the anus, on the postero-dorsal portion of the segment (fig. 18); the other group lies on the ventral surface of the caudal appendage.

All the glands of this, as well as those of the succeeding type, although unicellular, greatly exceed in size any of the hypodermal supporting cells; the gland, for example, represented in fig. 16 being 21 μ in length. Owing to this circumstance only those glands which lie in the thicker portions of the body wall, namely, those of the head and posterior portion of the sixth segment, are permitted to assume a position perpendicular to the body wall. The others, which are situated in the thinner portions of the latter, are compelled to lie in a plane parallel to the surface of the body, their ducts being bent sharply near their termination in order to reach the exterior.

The individual glands are long pyriform in shape, generally somewhat bent, and often strikingly similar in outline to an old-fashioned powder horn. At the base a crescentic theca of alveolar protoplasm is present in every case, staining deeply in iron-hæmatoxylin. Within the protoplasm is contained a clear oval or crescentic nucleus (*n.*) enclosing a large karyosome. The mucin which fills the gland is always split up into distinct fibrils, longitudinally arranged, thus giving the glands of this type a characteristic striated appearance. Filling the mouth of the gland is a deeply stained plug of protoplasm. None of the preparations studied showed a gland of this type in the act of discharging its excretion.

The glands of the third type (figs. 17 and 18, *gl.* 3) are much more numerous than those of either of the preceding types. Their precise manner of distribution, however, could not be determined with as much certainty as that of the preceding type, owing to the fact that they are not distinguishable on individuals mounted entire, but only in sections. A study of the latter shows that on the head the glands are scattered rather irregularly over its dorsal and lateral surfaces. On the trunk these glands accompany those of the preceding type, and are confined principally to the areas occupied by the latter. Thus on each trunk segment, with the exception of the sixth, they also occupy a narrow area just anterior to each ciliated band. Each of the trunk segments, from the second to the fifth, inclusive, thus possesses a glandular area which encircles it like a girdle, interrupted, however, by the ventral strip of cilia. In these areas the glands of the third type are, together with those of the second, crowded so closely that sections through these regions appear as though honeycombed with glands. In the areas of the sixth segment, previously described as occupied by glands of the second type, those of the last type are also present in such numbers that the hypodermis of these areas is filled with closely crowded glands, as may be seen in fig. 18. At the lateral margins of the ventral ciliated area, on each side, there is also an irregular row of these glands, extending the length of the trunk.

The form of the glands of this type is that of a short tube, considerably bent or contorted, rounded at the base and tapering toward the mouth. The contained secretion is granular, often exhibiting a reticular structure, staining dark gray with iron-hæmatoxylin, and unaffected by mucicarmine. A nucleus (*n.*) with a large plasmasome is usually to be seen near the fundus; the protoplasm surrounding it, however, is not clearly distinguishable from the secretion. These glands are met with in various stages of activity, some of which are illustrated in fig. 18. In contrast to those of the preceding type, discharging glands are frequently met with, as may be seen in the figure just mentioned. Those whose contents have been expelled, as in the example represented in fig. 17, exhibit in the portion devoid of secretion a black-staining residue which lines the walls and extends across from side to side as a coarse network.

Schmidt (1848) and Hallez (1879) describe rodlike bodies (battonets) as occurring in the cytoplasm of *Dinophilus*. Nothing corresponding to them exists in *D. conklini* unless it be the large mucous glands of the second type, which are somewhat rodlike in form. Korschelt (1882) found in *D. apatris* large glands on the ventral side and also on the dorsum of the last segment; to these he ascribed the function of secreting an adhesive fluid, and applied the name ''Klebsdrüsen.'' A group of pyroform glands similar in function, but of greater length, were also found by him on the caudal appendage; to these he gave the name ''Spinndrüsen,'' in allusion to the long threads of a mucus-like substance thrown out by them. Repiachoff (1886) studied the hypodermal glands of *D. gyrociliatus*, and found that glands similar to the Klebsdrüsen occur not only on the caudal appendage, but on the head and on the anterior part of the trunk as well, where they form ringlike groups corresponding to certain shining belts. Moreover, each of these glandular rings was placed before a corresponding ring of cilia. In the White Sea *Dinophilus* Schimkewitsch (1895) found a similar condition. These metamerically arranged glands Repiachoff considered to be true mucous glands, while the Klebsdrüsen were of a different nature. The results of these authors are difficult to reconcile with one another, in the light of my own observations, since, as has been shown, the true mucous glands are comparatively inactive, and would therefore be unlikely to function as adhesive glands. On the other hand, the non-mucous glands—those of the third type—are functionally very active and constantly emitting their secretion, and these might very well correspond to the Spinndrüsen, and possibly also to the Klebsdrüsen of Korschelt. A final decision, if it is possible to arrive at one, must however rest on direct observation of the living animal, and therefore be for the present postponed.

Muscles.—The body wall is provided with only two sets of muscles; one of these is composed of longitudinal muscle fibres which extend throughout the whole length of the trunk, the other comprises a few muscles traversing the head. A careful search with a one-twelfth oil immersion lens failed to yield any convincing evidence of the presence of a layer of circular or oblique muscles, although in one or two cases isolated circular muscles were found. One of these is shown in fig. 8, on the right side of the figure. The negative evidence in the case seems fairly conclusive, inasmuch as the longitudinal muscles, as well as other muscle fibres, stain intensely in the stain employed, iron hæmatoxylin. Other muscle fibres should therefore, if present, be also plainly discernible. In this connection it is to be noted that *Protodrilus* Hatschek (1880) also lacks the layer of circular muscles.

The longitudinal muscles are distributed in three pairs: (1) a medio-ventral pair lying in the mid-ventral line (fig. 6, *v.l.m. 1*); (2) a ventro-lateral pair (*v.l.m. 2*), the two members of which lie at an angle of about 45° from one another, as seen in transverse sections of the trunk, and (3), corresponding with the latter, in the dorsal half of the body, a dorso-lateral pair (*d.l.m.*). Each muscle is composed of a number of long spindle-shaped fibres, arranged in a single layer in close contact with the hypodermis. Of these fibres the medio-ventral pair of muscles has the fewest, not more than two or three being seen on each side, in transverse sections; while the ventro-lateral and dorso-lateral may show a dozen fibres apiece in the anterior region of the pharanx; the number decreases caudad of this point to six or seven fibres in the middle region of the trunk. Each fibre measures somewhat less than 1 μ in diameter in its thickest part. It was not possible to determine the precise length of the fibres, but it is probably about one-third or one-fourth of the length of the entire animal. Scattered along the muscles, apparently at irregular intervals, are small spherical nuclei (see fig. 4, *v.l.m. 2*), each containing a conspicuous karyosome and surrounded by a small and somewhat irregular mass of cytoplasm, the whole having much the appearance of a small mesenchyme cell. The cytoplasmic masses are, in transverse sections, seen to surround one or more muscle fibres. This relation is also shown in fig. 13, which shows a portion of one of the muscles of the head. The nuclei together with the surrounding cytoplasm, on account of their intimate connection with the muscle fibres, are evidently the undifferentiated portions of the muscle cells.

The posterior attachment of all of the longitudinal muscles is the same. As these muscles, passing caudad, reach the last segment they leave the hypodermis (fig. 8), cross the body cavity and, reaching the wall of the rectum, follow it to its union with the hypodermis. At this point the muscles are attached to the body wall by means of fine fibrillæ, formed by a brushlike subdivision of the muscle fibres. The anterior attachments of the three pairs of muscles are quite different. From the anterior part of the last segment the two muscles of the medioventral pair run close together in the ventral midline to the posterior border of the first trunk segment, where they diverge (compare figs. 5 and 6, *v.l.m. 1*) and, traversing this segment, are attached by a brush of fibrillæ to the posterior wall of the œsophagus, at the point where the latter joins the ventral hypodermis, that is, to the inner surface of the outer lip. The ventro-lateral muscles, on the other hand, preserve the same relative distance from one another throughout the trunk. On reaching the anterior edge of the mouth each of these muscles gives off one or two fibres which pass directly forward and pierce the lateral lobes of the brain, where they divide into minute branches. These penetrate between the hypodermal cells and are attached to the cuticle by conical enlargements of the terminal branches. This manner of attachment to the cuticle, common to all of the muscles terminating in the head, is well illustrated in fig. 23, *l.m.i.* The remainder of the muscle fibres rapidly converge cephalad of the mouth, and meet at the posterior surface of the brain in the midline. Here they break up into their component fibres. Some of these run directly cephalad to the hypodermis, piercing the brain on their way, meanwhile dividing into minute branches which pass between the hypodermal cells and attach themselves to the cuticle as described above. By far the greater number of the fibres, however, cross in the midline, forming a sort of chiasma, the fibres of one side passing over to the opposite side, where they pierce the lateral lobe of the brain on that side and, breaking up into fibrillæ, are attached to the cuticle of the antero-lateral aspect of the head, near the cells belonging to the first preoral ciliated ring (fig. 19, *v.l.m. 2*). The dorsal longitudinal muscles, on reaching the level of the mouth, bend downward and run directly forward, to penetrate the lateral portion of the brain of the same side. Here they meet the fibres of the ventro-lateral muscle of the opposite side, and accompany them to their attachment.

The muscles traversing the head cavity are four in number. The first of these is composed of but a few fibres, which pass in a dorso-ventral direction through the head cavity, just behind the brain (fig. 23, *d.v.m.*). The second traverses this space from side to side, while the third and fourth form a pair which cross it obliquely. All of these exhibit the usual brushlike subdivision of the ends of their fibres, and the attachment to the cuticle already described.

Muscles of the simple type described above have been found in all the species of *Dinophilus* whose finer anatomy has been carefully studied. Korschelt (1882) first found them in *D. apatris*, where they form two layers, one of circular and one of longitudinal muscles, the latter having the greater development. The muscles of *D. gigas* (Weldon, 1886) comprise delicate transverse muscles on the ventral side, and a bundle of fibres on each side of the trunk, running through its whole length, just above the lateral nerve cords. Weldon believed that the fibres of the circular muscles were continuous with processes of certain of the hypodermal cells. Harmer (1889*a*) mentions, in his paper on *D. tæniatus*, longitudinal muscles which are similar to those of *D. gigas*. Schimkewitsch (1895) studied the muscles of living examples of the White Sea *Dinophilus* (*D. vorticoides*) with the aid of methylin blue. Three layers of muscles were found in contact with the body wall: an outer circular layer, whose fibres have a regular metameric arrangement; a layer of oblique fibres, and a layer of longitudinal fibres, part of which are gathered together to form a pair of ventral longitudinal muscles. The latter run through the entire length of the trunk; at its anterior end some of them are attached to the body wall on the fold which separates the head from the trunk, while others pass into the head, cross, and penetrate the brain, as described for *D. conklini*.

3. *Nervous System.*

(*a*) CENTRAL NERVOUS SYSTEM.—The central nervous system comprises a brain, a pair of circumœsophageal commissures, and, continuous with the latter, a pair of longitudinal nerve trunks, provided with ganglia and transverse commissures.

The brain (figs. 1, 2, 19, 20 and 23), which is situated in the anterior portion of the head, is made up of two distinct portions, an internal portion composed of interwoven nerve fibres, the neuropil (*np.*), and an external portion formed of several layers of ganglion cells (*g.c.*), the outermost of which are in direct contact with the hypodermis. The neuropil, which in sections may always be readily distinguished by its yellowish tinge, as well as by its histological structure, has the general shape of a plano-convex lens, with the convex surface directed forward. It is, as may be seen in either horizontal or transverse sections, divided into three subequal lobes; one dorsal and median, and two lateral. The latter probably correspond to the "lobi optici" of Schimkewitsch (1895). Near its centre it is, in addition, pierced by a cleftlike aperture (fig. 2). Both the lateral incisions and the median aperture are traversed by the anterior portions of the longitudinal muscle fibres (*l.m.f.*) described in the preceding section. The general course of the nerve fibres which make up the neuropil is not immediately apparent; the first impression received is that of a closely matted and tangled mass. A careful inspection, however, shows that the fibres composing the three lobes for the most part run parallel to their surfaces, while those of the lower half of the fibrous mass, below the median aperture, run from side to side. The latter constitute the transverse commissure of the brain (figs. 2 and 20, *br.com.*).

The neuropil mass is covered on its anterior, dorsal and lateral surfaces by several layers of ganglion cells; its posterior surface is bounded by the cavity of the head, while its lower portion is separated from the ventral hypodermis by a narrow cleft (fig. 2). The ganglion cells are imperfectly divided into four groups, giving to the brain as a whole a lobed outline (figs. 1, 2, 19, 20 and 23). Three of these groups correspond to the median and lateral lobes of the neuropil, and are due to the same circumstance, namely, the arrangement of the anterior portions of the longitudinal muscle fibres. The fourth group covers the anterior surface of the brain, and is somewhat irregular in outline (figs. 19 and 23). Of these four groups the dorso-median is noteworthy in that it is situated comparatively remote from the rest of the brain, and is connected with the neuropil by a distinct bridge of nervous fibres (fig. 23, *n.f.*). In fig. 23 a fifth group of ganglion cells is also to be seen just below the brain, on its ventral side, and extending out toward the hypodermis. The presence of this group is, however, apparently unusual, since it could not be found in other examples.

The ganglion cells of the brain are all very similar in size and form, and have the appearance of being multipolar, axons and dendrites not being distinguishable in most cases. Some of the ganglion cells are, however, demonstrably bipolar, as, for example, the sensory neurons of the tactile cilia. It is probable that all the ganglion cells are of this type, namely, bipolar. The branching processes (dendrites) form a loose meshwork; some extending peripherally between the hypodermal cells; some—probably axons—extend centrally to enter the neuropil mass. In figs. 19 and 20 many of the ganglion cells appear as if seated on tiny papillæ of the neuropil. These papilla-like projections are, of course, only the central processes of the ganglion cells themselves which enter the neuropil and there divide into fibrillæ.

The cytoplasm of the ganglion cells, in contrast to that of the neighboring supporting cells of the hypodermis, stains rather deeply in iron-hæmatoxylin. On examination under a high power it presents a granular appearance (fig. 12). The nuclei of the ganglion cells are elliptical in outline and are very constant in size in the same individual, measuring from 1.42 x 2.25 μ in small individuals to 2.25 x 3.06 μ in the largest. They are rich in chromatin, which is divided into several large subequal granules, none of which exceeds the others sufficiently to be considered a karyosome, as in the nuclei of the other tissue cells. This peculiarity of the nucleus of the ganglion cells renders them, in this form, easily distinguishable wherever they occur. The same distinction, curiously enough, occurs in *Histriobdella* (*Histriodrilus*), as may be readily gathered from Foettinger's (1884) figures, although the author does not allude to it in the text.

Embedded in the posterior portion of the neuropil are cells having a cell-body indistinct in outline, and a large vesicular nucleus with a conspicuous karyosome. These cells are similar in form and size to those of the mesenchyme, which form with their branches a delicate network traversing the head cavity (figs. 19, 20 and 23), and are doubtless to be classed with them.

The circumœsophageal commissures spring from the ventro-lateral portions of the neuropil, below its lateral lobes, uniting at this point with the lateral portions of the transverse commissures, with whose fibres they are continuous (figs. 1, 20 and 23, *c.com.*). Each is at this point nearly round in section and lies in contact with the ventral hypodermis. Scattered over its surface are a small number of ganglion cells. As the two commissures reach the anterior border of the mouth they are reunited by a bundle of nerve fibres, the preoral transverse commissure (figs. 1 and 20, *pr.com.*). This is of uniform diameter throughout, and about one-third of that of the circumœsophageal commissures at this point. It lies partially embedded in the anterior wall of the œsophagus, just above the point where the latter meets the hypodermis of the ventral portion of the head, as is shown in fig. 23. Accompanying it, on its inner side, next to the œsophageal wall, are a few muscle fibres which terminate on either side in the body wall. In the series from which fig. 1 was taken, a series remarkably favorable for the study of the nervous system, clear evidences were found of nerve fibres which were given off to the inner surfaces of the hypodermal cells from the circumœsophageal commissures, at a point opposite to that of the junction of each with the preoral commissure. These nerve fibres have the appearance of being, to some extent at least, continuous with those of the preoral commissures. Moreover, a ganglion cell was found on each side, laterad of the junction of the preoral and circumœsophageal commissures, and having the appearance of belonging to the fibres just mentioned (see fig. 1).

Just posterior to its union with the preoral commissure, each circumœsophageal commissure gives off a large branch, the œsophageal nerve (figs. 1 and 3, *oes.n.*). This nerve at first runs in a dorso-posterior direction, following the œsophagus, and meeting in its course the ducts of the salivary glands (*s.g.d.*). It then accompanies these backward, but, before reaching the glands themselves, in the middle of the first trunk segment, it suddenly disappears. It possesses a large calibre throughout its course, and is elliptical or flattened in section, being closely applied to the outside of the œsophageal wall. Near its point of origin it is surrounded by a few ganglion cells, but these do not follow it but a very short distance (fig. 1).

After giving off the œsophageal nerve the commissures pass backward around the œsophagus, just below the lateral longitudinal muscles, and are now completely embedded in the hypodermis, just outside of the line of junction of the latter with the œsophageal wall (figs. 3 and 4). In section their form has changed from round to long-elliptical; this alteration being correlated with a decrease in the thickness of the hypodermis. The commissures are now so completely incorporated with the hypodermis that they can only be distinguished by their staining reaction and, to a limited extent, by their histological structure. At the posterior border of the mouth each circumœsophageal commissure, in the example from which fig. 1 was made, exhibits an opening or fenestra. Just beyond this point, in the posterior part of the first trunk segment, each commissure gives off a large nerve laterad to the ventro-lateral longitudinal muscle, which it accompanies for an indeterminate distance. It was successfully traced, however, only as far as the middle of the second trunk segment. This muscle nerve is flat and embedded in the hypodermis throughout its course, lying just beneath the muscle. It rapidly diminishes in thickness as it passes caudad, and for this reason could not be traced farther with certainty. At the point where the muscle nerve is given off ganglion cells reappear, and the circumœsophageal commissures may be considered to have passed into the lateral nerve cords. The latter, composed of nerve fibres longitudinally disposed, remain buried in the hypodermis while traversing the trunk to the posterior portion of the last segment. Here they end, after giving off a branch laterad to the body wall. They are situated apart, throughout their length, at an average distance of about one-half of the diameter of the body, or, as seen in cross sections of the trunk, about 60 degrees of the circle. They are thus slightly mesad of the ventro-lateral longitudinal muscles. In the second trunk segment and the anterior half of the third the ventral cords broaden out greatly, having a rather irregular contour on their mesial side, and are united by three transverse commissures. These commissures, broad where they join the longitudinal nerve cord, become so narrow at the midline that their continuity can only be demonstrated in good transverse sections (fig. 9). Above, below, and laterad of the nerve cords in this region of the body, but within the hypodermis, are numbers of ganglion cells (fig. 9, *g.c.*). The cell bodies of these latter cannot be distinguished from those of the surrounding hypodermis cells; their nuclei, however, are readily distinguishable, being precisely like those of the ganglion cells of the brain, except as to size, ranging from 1.12 μ x 1.87 μ to 1.80μ x 2.25 μ. Their average size is therefore nearly one-third smaller. These cells together form a long and diffuse ganglion, extending from the anterior of the second trunk segment to the middle of the third. At the latter point the ventral nerve cords rather suddenly contract, almost immediately widening again, and in the posterior half of the third trunk segment are again united by two commissures, situated apart at a distance of ca. 15 μ. Ganglion cells are also present here, forming a second pair of ganglia; the number of ganglion cells is, however, much less than in the preceding, and the second pair of ganglia are consequently of much less extent (fig. 9). The third pair of ganglia are similar to the second pair, but are composed of still fewer cells, and situated between the fourth and fifth trunk segments. Two commissures here join the ventral cords with one another. Between this pair of ganglia and the preceding, in the left ventral nerve cord, another opening or fenestra is seen in fig. 1. Between the fifth and sixth segments is the fourth pair of ganglia, again united by two transverse commissures, but possessing only a very few scattered ganglion cells. Posterior to this point, the ventral nerve cords, which have been gradually tapering caudad, suffer a sudden diminution in calibre. A fifth pair of ganglia in the sixth segment is possibly indicated by the presence of three or four ganglion cells on each side.

Nerves given off laterad from the ventral cords to the hypodermis were not observed, but this by no means argues their absence, since in the nature of the case they would be difficult to observe, unless of considerable size.

(*b*) SENSE ORGANS.—*The Eyes.*—These organs are situated, as shown in text fig. I, on the dorso-lateral surface of the head, about midway between its anterior tip and the second ciliated ring; their distance from one another is about one-half of the width of the head at this point. Their structure is essentially the same as that described for the eyes of other members of this group (fig. 10). Each consists of a cup-shaped mass, composed of reddish pigment granules, the mouth of which encloses a subspherical lens, slightly bilobed, the two lobes separated by a well-marked partition. Below the lens, in the lower part of the pigment cup, is a small space filled with a colorless fluid. Each eye is directed forward and outward, and lies embedded in the hypodermis ca. 4 μ below its outer surface. The cellular structure of the eye is not clear. Although the lens is sharply divided into two lateral halves, and in some cases the pigment cup faintly so, no nuclei are discernible within the eye itself, even when depigmented, nor could the eye be definitely connected with any of the adjacent cells. About the base of the pigment cup are clustered a number of ganglion cells belonging to the dorso-median group; it would perhaps be more correct to say that the base of the pigment cup is embedded in this group. Some at least of these cells, on account of their position, must function as percipient elements, although no differentiation serving this end could be observed. Korschelt (1882) describes a distinct optic nerve, connecting the eye with the brain; on the other hand Weldon (1886), Harmer (1889*a*) and Schimkewitsch (1895) all agree that, in the species studied by each, the eyes are embedded in the dorsal portion of the brain.

Sense Hairs.—Much time was spent in searching for these before they were recognized in fixed and stained material. In life the two larger sense hairs appear as tapering homogeneous threads of protoplasm, and such structures were sought for in sections. When they were finally identified by their position, they were found to be composed of a considerable number of cilia fused together, and borne by a cell essentially similar to those which constitute the adjacent ciliated bands (fig. 12). The smaller sense hairs (fig. 20, *t.cil.*) differ from the larger in being composed of fewer cilia, and borne by smaller cells. In view of the function of these hairs, a nervous connection was to be looked for. This was demonstrable in a few cases, the clearest of which is shown in fig. 12. Two sensory neurons, similar to the adjacent ganglion cells, in this case at least of the bipolar type, lie between the neuropil and the sense cell. Their peripheral processes are in close contact with the base of the sense cell, while their shorter central processes join with the neuropil. The composite nature of the sense hairs has been already noted by Schimkewitsch (1895) who speaks of the "Buscheln," and figures the pair of large sense hairs as made up of smaller elements. Miss Moore (1899) says of *D. gardneri* that "the head bears two tufts of long cilia in front . . . . these are probably of a sensory nature." Sense hairs of precisely similar structure, being composed of fused cilia, springing from cells like those which bear the locomotory cilia, are described by Meyer (1901) as found on the ventral surface of the umbrella of the trochophore of *Lopadorhynchus.*

Ciliated Grooves.—These structures have been noticed under the section on The External Form. Their histological structure offers nothing worthy of comment. The ciliated cells composing these grooves are similar to the other cilia-bearing cells of this form. There is no good evidence of any direct connection with the nervous system, although it is possible that they may be innervated by nerves given off from the preoral transverse commissure.

Problematical Sense Organs.—These are narrow oval areas, with the long axis of the oval vertical, measuring ca. 10 x 22 μ, situated, one on each side, in the constriction between the head and the first trunk segment, and slightly dorsad of the mid-level. A section through one of these organs is represented in fig. 11. The cuticle is seen to be thickened over the whole ciliated surface, and especially at its centre. In the middle of each the cilia are lacking over a space about one-third of the diameter of the whole, their place being supplied by a number of spherical bodies, borne on slender rods, which project barely above the surface of the cuticle. Midway between the outer and inner surfaces of the body wall the rods stain more intensely and appear to thicken, forming a well-marked zone. Centrad of this zone the rods are just visible, but can with care be seen to terminate against the basement membrane. On the inner side of the basement membrane, at this point, a group of œsophageal muscle fibres are inserted (*oes.m.*). In the belief that this curious structure was sensory in function, a careful search was made to determine whether a demonstrable connection with the nervous system was present, but none could be found.

From the description given above it is apparent that *D. conklini* possess a very much simplified nervous system of the ladder type, and one which is embryonic in many particulars, as, for example, in the close association of the whole with the hypodermis (ectoderm), and especially the slight differentiation of the portion belonging to the trunk, where the lateral trunks with their ganglia are not merely in contact with the body wall, but included in it.

The first description of the nervous system of *Dinophilus* is that given for *D. apatris* by Korschelt (1882). The studies of this investigator were confined almost wholly to entire individuals, living or mounted in balsam. From one of the latter, stained in alum carmine, he described and figured a brain, from which arose two pairs of nerves: one pair running forward to the eyes, while the other, which passed backward, he regarded as the roots of longitudinal nerves.

The next paper on *Dinophilus*, that of Weldon (1886), gave a fairly complete account of the nervous system of this species (*D. gigas*). According to Weldon, the brain, which fills the preoral lobe, consists of a central mass of nerve fibres, surrounded by ganglion cells, which are, as indicated by his figures, in close contact with the hypodermis. From the brain arise the lateral nerve cords, which are also in close contact with the hypodermis, and consist of nerve fibres and ganglion cells. The latter, however, almost entirely disappear in the posterior region of the body, and apparently show no traces of separation into ganglia. Transverse commissures also appeared to be wanting. In regard to the last two points, there seems room for reasonable doubt if more perfect series of sections than it was at that time possible to make would not reveal the presence of both ganglia and transverse commissures in this species.

In respect to the points last mentioned, the account of Harmer (1889*a*) is much more satisfactory. This author found in *D. tæniatus* a brain definitely separated from the hypodermis, and a nervous system of the ladder type, which, although remaining in contact with the body wall, lies outside of its basement membrane. The ganglion cells, although investing the nerve cords along their whole length, are united at intervals into compact groups to form five pairs of well-defined ganglia, each of which is united by a transverse commissure. Each pair of ganglia corresponds to a trunk segment, although situated slightly posterior to the middle of the segment, as indicated on the exterior by the constrictions and ciliated rings.

In the same year with Weldon's paper (1886) there appeared one on *D. gyrociliatus* by Repiachoff. This investigator described and figured the brain of this species and the anterior portions of the two circumœsophageal commissures. The brain is, as in the other species, composed of a central mass of nerve fibres (neuropil) invested on all except its posterior surface with ganglion cells. These latter are closely united to the ectoderm, as in *D. gigas*, whereas in *D. tæniatus* they are distinctly marked off from it.

Schimkewitsch (1895) has, in his account of the structure of *D. vorticoides*, found in the White Sea, given the most complete account of the nervous system of *Dinophilus*, as well as of other organs. The nervous system of this species is, as a whole, essentially like that of *D. tæniatus*, but differs from it in two important particulars. The ganglion cells do not invest the lateral nerve cords throughout their length, but are completely segregated into ganglia, the first pair of which, together with their transverse commissure, lies entirely outside of the hypodermis. If the nervous system be used as a criterion, then *D. vorticoides* has reached the highest stage of development attained by any member of the group thus far investigated. Judged in this aspect, *D. gigas* should be placed at the foot of the scale; *D. conklini* second, *D. tæniatus* third, and lastly *D. vorticoides.*

Harmer (1889*a*) has made a somewhat detailed comparison between the nervous system of *Dinophilus* and that of the archiannelids. *Dinophilus* agrees with all of the members of that somewhat heterogeneous group in the general plan of the nervous system and in its close relation to the hypodermis (ectoderm). With *Protodrilus* (Hatschek, 1880) and with *Histriobdella* (*Histriodrilus,* Foettinger, 1885) it further agrees in the separation of the lateral halves of the ventral nerve strand. However, in a new species of *Histriobdella* described by Haswell (1900) the lateral halves of the ventral nerve cord are completely fused. Goodrich (1901), in discussing the systematic position of *Saccocirrus,* has drawn attention to the well-known fact that the epithelial position in this form is shared by chætopod annelids belonging to widely separated groups, as, for example, the *Eunicidæ* (Spengel, 1881), *Syllidæ* (Malaquin, 1893), *Polynoidæ, Chætopteridæ, Maldanidæ* (MacIntosh, 1885), and *Myzostomidæ* (Graff, 1877). The same may naturally be said of *Dinophilus*. Moreover, two other special features, namely, the separation of the lateral halves of the ventral nerve cord and the subdivision of the transverse commissures, it shares with many *Hermellidæ* and *Serpulidæ* (Meyer, 1886). Both the epithelial position of the nervous system and the separation of the nerve cords are found in *Nerilla* (Pereyaslawzewa, 1896), which is unquestionably a polychætous annelid, while with the nervous system of *Ælosoma* (Brace, 1901), the most primitive member of the Oligochæta, there is the closest resemblance. For example, *A. tenebrarum*, described by Miss Brace, possesses not only a brain closely soldered to the hypodermis, but also widely separated ventral nerve cords, metamerically arranged groups of ganglion cells, and two or more transverse commissures for each segment, all completely embedded in the ventral hypodermis.

This widespread ectodermal position of the nervous system is of course readily explained as a retention on the part of these forms of an embryonic condition—a permanently arrested stage of development—apparently correlated with their small size and the resulting simplification of their economy. That the same explanation will apply to *Dinophilus* is sufficiently obvious; the more so in the light of the researches of Schimkewitsch (1895) on the embryology of this form, as well as the evolution of the nervous system, as seen in the differing stages of development shown by the various members of the group, and described above.

There remain three special features of the nervous system of *D. conklini*. The first of these is the presence of a preoral transverse commissure. This structure may be accounted for in one of several ways. In the first place it might be supposed to represent a commissure originally postoral, and belonging to the trunk, but which has become preoral in position by the shifting of the mouth in a caudal direction. This would be a perfectly allowable assumption, supported by analogy with related forms, since in both the flatworms and annelids the position of the mouth is by no means a fixed one, but quite subject to shifting. However, although the posterior limb of the triradiate mouth does extend caudad into the trunk region, the evidence of any considerable movement caudad on the part of the mouth as a whole is too slight to lend this explanation of the occurrence of a preoral transverse commissure any considerable degree of probability.

In the next place this commissure may be regarded as having arisen entirely *de novo* in response to the peculiar physiological needs of the animal. Such an explanation is certainly permissible, but it would be worth while first to inquire whether a corresponding structure exists in any of those groups to which *Dinophilus* can be considered related, and from which it may have derived this structural peculiarity. Such a group is found in the annelids, whose larva, the trochophore, represents either an ancestral condition, or else a stage interpolated in the ontogeny very early in the racial history. In this larva, thanks to the researches of Kleinenberg (1886), confirmed by Meyer (1901), it is known that at an early stage there is present, embedded in the ectoderm, beneath the prototroch, a circular cord of nerve fibres, considered by Kleinenberg as the primitive nervous system of the larva, and homologous with the nervous system of the medusa. At a late period in the development, during the metamorphosis of the larva into the segmented worm, this nerve-ring is crossed, on the future ventral surface of the worm, by the circumœsophageal commissures, forming a structure shaped like the letter H (see Kleinenberg's fig. 31, Taf. IX). This intercalated segment of the nerve-ring persists for a long period, but finally suffers complete absorption and disappears. Now, one of the chief functions of the nerve-ring is that of innervating the prototroch, the principal organ of locomotion of the larva, and of controlling its motions. If, then, the prototroch should persist, it would be quite probable that at least a portion of the nerve-ring would persist with it, and it would quite likely be that portion which persists longest in the ontogeny. This, I believe, is what has happened in *Dinophilus.* Moreover, there are also indications of the persistence of the lateral portions of the nerve-ring (see fig. 1). When it is remembered that the second preoral ciliated band is in all probability homologous with the prototroch of the annelid larva, it will be apparent that there are good reasons for considering the preoral transverse commissure of *Dinophilus* as the persisting remnant of the nerve-ring of the trochophore larva of the annelids, preserved not merely by force of inheritance—since a multitude of examples might be cited to show that this is not of itself sufficient to save an organ or structure from disappearance—but rather by the physiological needs of the animal.

The œsophageal or stomatogastric nerve is not only found in *D. gigas* (Weldon, 1886), *D. tæniatus* (Harmer, 1889*a*), and *D. vorticoides* (Schimkewitsch, 1895), but in annelids generally, as, for example, *Oligognathus* (Spengel, 1881) and *Saccocirrus* (Fraipont, 1884).

The nerve innervating the ventro-lateral longitudinal muscles has not yet been described in any species of *Dinophilus*; but renewed research of other forms might bring it to light. Its close connection with the muscle recalls the precisely similar relation found between the longitudinal nerves and muscles found by Meyer (1901) to exist in the trochophore larva of *Lopadorhynchus*, and strongly hints that, as in that form, it may be due to a common origin from the ectoderm.

4. *Alimentary Canal.*

The alimentary canal of *D. conklini* does not differ in its essential features from that described for other members of the group, and resembles very closely that of *D. apatris* and *D. gyrociliatus*. On the ventral side of the head is the mouth opening, which is triradiate or Y-shaped, the vertical limb of the Y being directed caudad. The latter is not confined to the head segment alone, but extends backward into the first segment of the trunk as far as its middle region (see text fig. I and fig. 23). Korschelt (1882) has described a similar condition in *D. apatris*, the mouth in this species extending back from the head into the short segment-like piece which lies between the head and the first trunk segment. In Schmidt's drawing (1856) of *D. gyrociliatus* the mouth is represented as confined exclusively to the head, but in another of the same species published by Meyer (1886) the relation of the mouth to the head and trunk is shown to be the same as that just described for *D. conklini*. The possible significance of this relation will be discussed later.

The mouth leads dorsad directly into the œsophagus; caudad it opens into the cavity containing the proboscis (fig. 23), an organ common to all or nearly all of the members of this group. Forming the dorsal wall of the proboscis cavity and separating it from the œsophagus is a crescentic fold extending across the posterior wall of the œsophagus and partially closing its lumen; the two lateral halves of this are called by Harmer (1889*a*) "the inner lips" (figs. 4 and 23, *i.l.*), in contradistinction to "the outer lips" (*o.l.*) which are formed by the union of the walls of the body and œsophagus. From the inner lips the œsophagus ascends, curving slightly backward, to the dorsal body wall, where it bends sharply to the rear and, pursuing a horizontal course for a short distance, reaches the stomach. This it enters at a point considerably dorsad of the mid-level. The lumen of the œsophagus in its ascending portion is scarcely more than a cleft, being very narrow in its transverse diameter, although long in an antero-posterior direction. In its anterior portion, however, next to the wall of the œsophagus, the lumen widens out suddenly, forming here a small open channel. The narrow portion of the œsophageal lumen answers to that limb or radius of the Y-shaped mouth which is directed caudad, the open channel to the anterior two limbs. At the upper end of the ascending ilmb the lumen gradually becomes circular in section, and remains so for the remainder of its course. In *D. gyrociliatus* Schmidt (1857), and in *D. apatris* Korschelt (1882), have each described a proventriculus (Vormagen), which is simply an enlargement of the horizontal limb of the œsophagus. In isolated individuals of *D. conklini* there is an indication of such a structure in a slight dilation of this portion of the œsophagus, but this dilation is apparently not permanent, but merely temporary.

The cells which form the walls of the œsophagus are relatively large, and very similar, except in their size, to those of the body wall. Correlated with the shape of the œsophageal lumen in its ascending limb is a marked difference between the height of the cells of the lateral and the anterior and posterior walls, since the exterior of the œsophagus in section preserves a regular oval or circular contour. Those which form the anterior and posterior walls are low and cuboid, while those composing its lateral walls are high, and, although rather irregular, both in size and shape, may, on the whole, be considered columnar in form (cf. figs. 3 and 23). The cells of the remainder of the œsophagus are fairly regular both in form and size, usually cuboid, arranged in a single layer. All of the œsophageal cells are clothed with a thin cuticle, a continuation of that covering the body, and also bear long cilia. These spring from distinct basal knobs, which form a uniform layer a short distance below the cuticle, a narrow subcuticular layer intervening.

In many individuals a large number of the nuclei of the œsophageal wall are undergoing a process of degeneration, some of the stages being represented in figs. 31 and 32. The various stages of this process have not been carefully studied, but it is evident that bound up with this process, possibly resulting from it, is the expulsion of the cell from its epithelium. Such a cell is shown in fig. 31. Two possible explanations of this phenomenon present themselves. The function of the cells may be that of secretion, and their degeneration and expulsion the result of old age, like the "cellules de ferment" of the mid-intestine of *Lagis koreni*, described by Brasil (1904). On the other hand the degeneration and expulsion of these cells may have for its purpose the liberation of the cell contents, which have acquired digestive properties, in the lumen of the œsophagus. This would then be an example of holocrine secretion (Ranvier).

Closely connected with the œsophagus is an organ which is common to all members of this group, and variously termed "proboscis," "muscular appendage," "Pharanx," and "Pharangealtasche" by different authors. On account of its brevity and definiteness I prefer to use the earlier one of "proboscis" ("trompe," Hallez; "Rüssel," Korschelt). The proboscis of *D. conklini* lies just behind the mouth, and in side view presents a reniform outline, its concave surface directed forward and applied to the posterior wall of the ascending limb of the œsophagus (fig. 23). In cross section (figs. 4, 5, and 23, *pro. 1* and *pro. 2,* and fig. 30) it is elliptical, the long axis of the ellipse lying transversely. The greater portion of this organ lies within the body cavity between the two limbs of the œsophagus, and practically filling up this space. The anterior and more pointed end of the proboscis (*pro. 1*) projects into the pocket-like cavity opening between the inner and outer lips, and is covered by a reflection of the cuticle which lines the cavity. This portion of the proboscis also differs histologically from the remainder, being composed of cells substantially similar to those of the œsophageal wall, but slightly darker and less distinctly granular, which pass over, on the dorsal side, into those forming the inner lips, as shown in fig. 23. Beneath the fold of cuticle which connects the proboscis with the outer lips, in the same figure (23), may be seen a network of protoplasm which finally unites with the epithelium of the outer lips (*o.l.*). This network encloses a nucleus, in the section figured, and is, together with the tip of the proboscis, as well as the inner lips (*i.l.*), merely a continuation of the epithelium forming the œsophageal wall. Laterad of the midline this epithelium is clearly seen to be continuous over the whole of the pocket, from the upper lips to the posterior margin of the mouth. This continuity of the œsophageal epithelium is still more plainly seen in *D. tæniatus* (Harmer, 1889), and in *D. vorticoides,* as seen in the figures of Schimkewitsch (1895). In both these forms it passes unbroken over the proboscis to the posterior border of the mouth. This is especially well seen in Schimkewitsch (Taf. VI, fig. 37). The remainder of the proboscis, that is, all of the organ behind the pointed tip, presents a histological structure which is extremely curious. This peculiarity of structure has been either entirely misunderstood by previous writers or passed over with scant notice. A careful study of sections shows that the part in question, constituting the major portion of the proboscis, is divided into about thirty narrow chambers by as many transverse cuticular partitions (fig. 23, *pro. 2*), regularly placed from one to three micra apart. These partitions bear on each of their two surfaces a single layer of slender fibrillæ, of uniform diameter, and having the same general appearance and staining reaction as muscle fibres (figs.

4, 5 and 23, *pro. 2*). The fibrillæ in each layer are parallel to one another, and accurately spaced about 1.5 μ apart, running diagonally from one side to the other of the proboscis, at an angle of approximately 45 degrees to the horizontal plane. The fibrillæ on opposite sides of the same partition, however, are not parallel, but, while intersecting the horizontal plane at the same angle, the fibrillæ of one layer cross those of the other at right angles. Thus it follows that only the fibres of alternating layers are parallel, while those of any two consecutive layers run at right angles to one another. As a result of this arrangement, in cross sections through the proboscis, in which two layers of fibrillæ are included, these latter, being seen simultaneously, create the appearance of a lattice work, which is very regular whenever the section is parallel to the partitions (fig. 30). The spaces between the partitions are filled with a pale and vacuolated cytoplasm, near the centre of which is a much flattened nucleus, with a large karyosome. The greater portion of the proboscis is thus composed of a series of disk-like cells, placed like coins in a pile, and separated by cuticular partitions. Near the centre of each is a nucleus, while each of its faces bears a layer of fibrillæ. This peculiar and somewhat complex structure demands an explanation, but it must be confessed that I have none to offer, based on my own observations, inasmuch as living material has been inaccessible to me since the necessity of its study in regard to the point in question became apparent. Some of the observations of Korschelt (1882), made on *D. apatris*, however, bear on this point. This investigator described and figured the two portions of the proboscis, but interpreted the striated appearance of the hinder portion as produced by *circular* muscles. He then proceeds to say: "Die ganze Rüssel strekt sich dabei und verlängt sich durch Contraction der Ringmuskeln." In speaking of the degree of extension of the proboscis he states that "seine Vorderende bis in die gegend der Augen vorgeschnellt werden." So great a degree of extension could hardly be accomplished by the action of extrinsic muscles alone. Moreover, the diagonal fibrillæ by their contraction would produce the same mechanical effect as circular muscles, viz., an extension of the proboscis brought about by a lessening of its diameter. In view of this fact, and of the observations of Korschelt, it may, I think, be permissible to assume, provisionally at least, that the function of the diagonal fibrils of the proboscis is the extension of that organ.

In addition to the intrinsic musculature the proboscis of *D. conklini* is also provided with a set of extrinsic muscles. These are eight in number, arranged in four pairs: protractors, flexors, retractors, and levators. These are composed of but one or two fibres apiece. The first of these muscles, the protractors (fig. 5, *pro.pr.*), lie close together near the midline, beneath the proboscis. They are attached to the ventral body wall, just inside of the attachment of the median ventral longitudinal muscles. From here they pass directly backwards, and are inserted on the ventral side of the proboscis about midway of its length. At their attachment and insertion these, as well as the other proboscis muscles, display the brushlike tufts, formed by division of the fibrils, that were observed in the case of the trunk muscles. The second pair, the flexors (fig. 4, *pro.f.*), join together the two ends of the proboscis, passing over its convex anterior face. The retractors (fig. 4, *pro.r.*) are attached to the ventro-lateral portion of the horizontal limb of the œsophagus, above the proboscis, and descend to their insertion in its anterior portion. The levators are attached to the lateral body wall and inserted on the sides of the proboscis, near its middle.

The stomach is a cylindrical or barrel-shaped organ, occupying the body cavity from the anterior limits of the third trunk segment to the middle of the fourth. These two segments, it will be remembered, far exceed the others both in length and diameter, so that the stomach is therefore a relatively large organ, its length being nearly one-half that of the trunk. Its diameter approaches that of the body cavity of the segments in which it lies; the space that remains between the stomach and body wall being reduced to a narrow cleft. The anterior end of the stomach is more or less distinctly truncate; its posterior end, on the other hand, is conical, tapering to join the intestine. This junction, like that with the œsophagus, is dorsal to the median axis.

The stomach wall (figs. 6 and 35) is from 11 μ to 30 μ in thickness, and composed of a uniform layer of cuboid or low columnar cells, whose inner ends bear long cilia. Each cell displays at its central end a shallow layer of homogeneous protoplasm, staining deeply in iron-hæmatoxylin after fixation by sublimate, less densely after Flemming's mixture; just below this layer are the close-set basal knobs of the cilia. The body of the cell consists of dark staining and much vacuolated cytoplasm, within which, usually near the base of the cell, is an ovoid or spherical nucleus, provided with the usual karyosome. The cytoplasm of the cells of the stomach presents a somewhat varied appearance, according to the fixative employed. Sections cut from material fixed in corrosive sublimate (fig. 6) show the cytoplasm much vacuolated, indeed so much so that the protoplasm is reduced to scarcely more than a coarse and densely staining reticulum. Within the meshes of this reticulum may be discerned, moreover, pale yellow, somewhat refractive granules. In material fixed in Flemming's fluid (fig. 35) the picture is strikingly different. The cytoplasm presents the same vacuolated appearance, but here each vacuole constantly encloses a yellowish-brown spherule; while in many individuals the cells moreover contain many black-stained inclusions of the most varied shapes, some of which are shown in fig. 35. That these latter are fatty in their nature is indicated by the fact that they are visible only in material fixed with a mixture containing osmic acid, and also by their intense blackness. The yellowish contents of the vacuoles, whether appearing as pale granules or as spherules, is doubtless only the precipitate of the fluid contained in them during life.

The above description applies to the majority of the cells which make up the stomach wall. In addition to these, and scattered among them in considerable number, are unicellular glands (fig. 6, *g.gl.*, and fig. 34). These stain more deeply than their neighbors, being especially dark at their bases. Their cytoplasm is not visibly vacuolated, and presents a granular appearance. In the example shown in fig. 34 a portion of the cytoplasm at the central end of the cell is seen to have been transformed into a coarsely granular secretion, which is escaping into the lumen of the stomach through a break in the cell wall. These cells have evidently a digestive function. Another peculiar structure was also frequently noted, which may be considered as having to do with the digestive functions, although this is not certain. Embedded in the stomach wall of many individuals there were frequently observed large spherules, whose diameter was approximately one-half of the thickness of the stomach wall, and which possessed a staining reaction similar to that of the surrounding cells—although perhaps a trifle darker—and having a homogeneous appearance (fig. 33). Contained within this spherule there appears constantly a spherical mass of chromatic substance, approaching in size and appearance the nucleolus of the surrounding cells. In addition there is also scattered through the spherule tiny granules of chromatic material. In close contact with the spherical body is a cap-shaped nucleus, *n*. That this close association with a nucleus is not accidental is indicated by the fact that it was found in ten successive instances. The whole structure—the spherical body with its chromatic enclosures, its homogeneous appearance, and its close contiguity to a true nucleus—closely resembles the figures given by Brasil (1904) of the "grosses boules hyalin" found in the mid-intestine of *Lagis koreni*, and which are concerned with the degeneration of the cells in which they occur.

The intestine (figs. 7 and 8, *int.*) takes its rise from the posterior portion of the stomach, dorsad of the median axis of the animal, whence it runs caudad to the anus in a nearly straight course, with but a slight sigmoid flexure. Like the stomach and œsophagus, it is lined throughout its course with long cilia. The anus, as already described, opens at the posterior termination of the trunk, just dorsad of the caudal process. The outer diameter of the intestine in its middle portion is about one-half of that of the stomach, but is contracted both at its junction with the stomach and at the anus. The intestinal wall is approximately 3 μ in thickness and composed of a single layer of cells which vary much in form, from a flattened squamous type to the cubical. This irregularity in the form of the constituent cells of the intestinal wall is associated with an irregularity in the contour of its inner surface, the latter being raised into numerous longitudinal ridges rather irregularly arranged, most numerous and attaining their greatest height midway between stomach and anus, and disappearing near the two latter points. The cells themselves present the same cytological characters as those of the œsophagus, namely, a thin cuticle, a narrow subcuticular border, a layer of end knobs, from which arise the long cilia, and a clear and transparent cytoplasm, enclosing an ovoid nucleus with a karyosome.

The musculature of the alimentary canal is very slight, aside from that of the proboscis and the few fibres which accompany the preoral transverse commissure. The latter are to be reckoned with those of the alimentary canal, since they serve to draw together the lateral halves of the mouth. No traces were found of the radially arranged muscles about the mouth described by Korschelt (1882). The largest and most evident muscles are comprised in two small groups, one on either side of the vertical limb of the œsophagus, passing from its lateral walls to the body wall on either side (fig. 3, *œs.m.*). These serve, as do similar muscles in annelids and other forms, to dilate the œsophagus. A few muscle fibres encircle the œsophagus at irregular intervals, and are only visible in longitudinal sections, where they appear as black points on the outer surface of the œsophageal wall. Some of these are represented in fig. 23. It is possible that such fibres are present also on the stomach and intestines, but I have not been able to satisfy myself of their presence. There is however, encircling the posterior end of the intestine a very short distance anterior to the anus, a muscle composed of one fibre, which thus serves as a *sphincter ani* (fig. 8, *int.m.*).

The glands occurring in the epithelium of the alimentary canal have already been mentioned. There remains to be described the "salivary glands" (Speicheldrüsen, O. S. Schmidt), and a set of huge glands which I have termed "cephalic glands." The description of these latter glands is brought into this section not so much because of their hypothetical relation to the digestive system, as for the sake of convenience.

The salivary glands (fig. 5, *s.gl.*) are similar to those of *D. gyrociliatus* (Schmidt, 1856; Repiachoff, 1886) and *D. apatris* (Korschelt, 1882). They consist of two groups of large unicellular glands, each group numbering in the neighborhood of a dozen cells, situated laterad to the œsophagus, in the angle formed by the junction of the latter with the stomach, and forming an ovoid or pyriform mass. The cytoplasm of these gland cells stains from a brownish yellow to a deep black in iron-hæmatoxylin, and has a homogeneous, compact appearance, but frequently encloses vacuoles of a lighter tint. The nuclei are spherical and contain large nucleoli. From each cell proceeds a slender duct, which passes along each side of the horizontal limb of the œsophagus, in contact with it, the ducts of each side uniting to form a bundle (fig. 4, *s.gl.d.*). Arriving at the ascending limb of the œsophagus, each bundle splits up into its component ducts. These enter the œsophagus, penetrating between the cells of its lateral and posterior walls, each at a different point, and open into its lumen (fig. 3, *s.gl.d.*). In *D. apatris* these glands are said by Korschelt to open between the œsophagus and proventriculus. In *D. gigas* (Weldon, 1886) gland cells are found lying outside of the pharangeal (œsophageal) wall, while similar glands lie at the base of the hypodermis forming the outer lips. Harmer (1889*a*) describes "racemose" salivary glands opening into the anterior division of the œsophagus. Schimkewitsch (1895) says of the salivary glands of *D. vorticoides:* "sie öffnen sich mit einigen Bündeln der ganzen Ösophagus entlang seitlich und naher zum Rucken." He also speaks of them as "mit Mucin erfüllt." It is quite evident that in *D. conklini* the contents of these glands is not mucin, although staining densely in hæmatoxylin, for in all of my preparations which were stained in Meyer's mucicarmine, a specific mucin stain, not one of these glands is tinged with it in the slightest degree, while the hypodermal mucous glands are all deeply colored.

The cephalic, like the salivary glands, form two groups or complexes of large unicellular glands. These are situated in the dorsalmost portion of the head cavity, just in front of the vertical limb of the œsophagus, each group symmetrically disposed a short distance on either side of the midline (see text fig. III, A. and B). Each gland cell, of which each group contains three to five, is pyriform in shape (fig. 22), with the smaller end directed downwards, and continued as a very slender duct. The ducts from each group unite to form a bundle (text fig. III, A, and fig. 20, *c.gl.d.*). Each of these passes downward and slightly forward, penetrating in their course the lateral portions of the brain. On meeting the ventral hypodermis the ducts of each side diverge, most of them turning inwards (mesiad), and, penetrating the hypodermis, open on the ventral surface; the mouths of the ducts forming a line transverse to the long axis of the animal, just posterior to the anterior end of the head. Just before its termination, each duct displays a bulbous enlargement, forming a small reservoir. The cephalic gland cells much resemble those of the salivary glands in their cytological characters and staining reaction. Like the latter, the protoplasm of the cephalic glands absorbs many chromatin stains with avidity, being stained with especial intensity in Delafield's hæmatoxylin and in carmine, while unaffected by mucicarmine. With iron-hæmatoxylin it is usually colored only a dark gray. In certain cases, as in the one represented in fig. 22, intracellular spaces, which previously had evidently been occupied by secretion, were present in the cytoplasm.

Glands corresponding to the cephalic glands have been described only in the account given by Schimkewitsch (1895) of *D. metameroides*, although this author suggests their occurrence in *D. tæniatus*, inferring this from Harmer's (1889*a*) description and figures of the brain.

The function of the cephalic glands is problematical. Their situation, just anterior to the preoral field of cilia which serves to sweep food particles into the mouth, suggests that they may perform a digestive function. Whether this is the case or not, their great size indicates that their function must be an important one in the economy of the animal.

5. *Excretory Organs.*

Nephridia.—Dinophilus conklini possesses five pairs of nephridia, metamerically arranged and corresponding to the five posterior trunk segments. The first of the five pairs differs from the others in that its structure is relatively much more complex; for that reason it will be more convenient to defer the consideration of this pair to the last, and to describe first the simpler structure of the posterior four pairs. These are very tenuous and ill defined in structure, in fact so much so that for a long time I failed to recognize them as definite organs, and mistook them for mere strands of mesenchymatous or connective tissue. In general structure, however, they were found to correspond closely to the nephridia of *D. gyrociliatus*, as figured by Meyer in 1886. Each nephridium is a thin-walled tube, ciliated throughout, and composed of some four to six cells. Throughout its length it adheres closely to the body wall, except in the case of the nephridia of the fifth pair, which float more or less freely in the body cavity. The course of each nephridium is winding, but its general direction is transverse to the long axis of the body, the morphological inner or central end being dorsal, the outer ventral. The lumen is from 1–2 μ in diameter, and widest near the middle of its course. At the central (dorsal) end (fig. 24) of each nephridium it gradually becomes narrower, and finally terminates blindly in a flat mass of granular protoplasm, containing, besides one or two nuclei, greenish refringent bodies, irregularly ovoid in shape. Goodrich (1897) has described similar bodies in the nephridia of *Sternaspis.* Toward the peripheral (ventral) extremity of the nephridium, which usually lies just laterad of the ventral nerve cords, the lumen again slightly decreases in calibre. The precise point where the external opening is situated could in no case be determined with certainty, although prolonged and careful search was made with the highest powers at my command. This difficulty is caused partly by the small size and lack of definiteness of the parts concerned, and also by the fact that it is only possible to study the nephridia in sections, since the opacity of the living animal and the close proximity of the ciliated walls of the alimentary canal make a study of the nephridia during life extremely difficult. It is, however, doubtless true also that the external openings are usually closed, and open for discharge only at intervals, as happens in the nephridia of some annelids, *e.g.*, *Ælosoma.* Shearer (1906) finds that each of the ducts of the nephridia of *D. tœniatus* terminates in a vacuole in the ventral hypodermis, but that no external opening could be demonstrated.

The nephridia forming the first pair are, as already stated, relatively complex, and are also much larger, more definite in structure, and more readily observed. Nevertheless, the tracing out of the entire course of these nephridia is by no means a simple task, and has been accomplished solely by reconstructions from sections, one of which is shown in text fig. IV, representing the left anterior nephridium, as viewed from the interior of the body of the animal. The morphological central end (text fig. IV, figs. 25*a* and 26*a*, *c.e.n.*) begins as a slender strand of protoplasm, attached to the lateral wall of the first segment. As it passes caudad it widens out, and in the second trunk segment becomes triangular in shape, thin at its edges, the external edge attached to the body wall and to neighboring parts of the nephridium, the inner or mesial edge frequently extending to meet and fuse with its fellow of the opposite side. One or two nuclei are seen to lie in this portion of the nephridium. Within its substance, near its ectal margin, beginning near the anterior limit of the second trunk segment and running parallel to the long axis of the body, is a canal, the *inner canal* of the nephridium (text fig. IV, figs. 25 and 26, *i.c.n.*), its anterior end conical and terminating blindly in the protoplasm. This canal is lined with long cilia directed caudad, and has a maximum calibre of about 3 μ. Near the middle of the second segment the inner canal contracts rather suddenly to about one-third or one-fourth of its former diameter, and sends off a slender connecting branch to the *lateral glandular portion* of the nephridium (text fig. IV, figs. 25*c–e*, and fig. 26, *l.g.n.*). The latter is a large flat biscuit-shaped mass of protoplasm, irregularly lobed or incised, and pressed closely against the lateral body wall. On its mesial side it is in contact with the salivary gland (*s.gl.*). Within the lateral glandular portion are three or four large spherical nuclei, containing very large karyosomes. No cell boundaries are visible. The cytoplasm has a coarsely granular appearance and stains very densely. The whole mass is permeated throughout by a

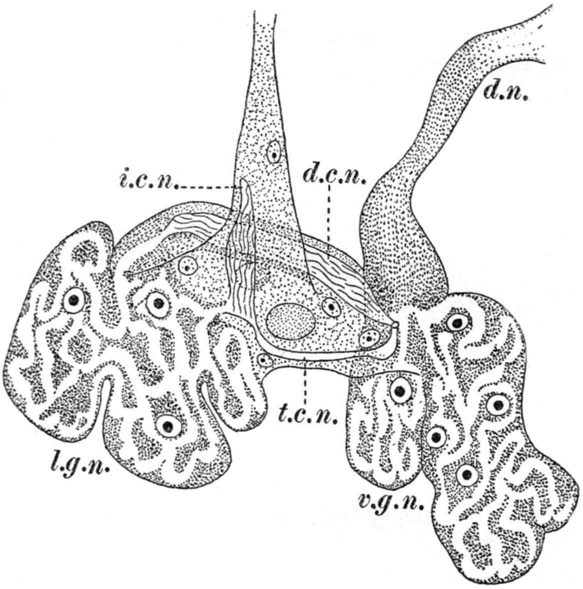

Fig. IV.—Nephridium of the first pair, belonging to the left side, as seen from the interior of the body. Reconstructed from sections. × 1053. For explanation of reference letters see Explanation of Plates.

system of ramifying intracellular spaces or canals, forming a veritable labyrinth. These canals are filled with a pale staining granular substance, probably the precipitate of a fluid.

After sending off its branch to the lateral glandular portion of the nephridium, the inner canal continues backward a short distance, its diameter meanwhile diminishing to ca. 0.5 μ, then bends almost directly downward, widening as it does so, and passes into the transverse canal (text fig. IV, figs. 25*e* and 26*a*, *t.c.n.*). The length of the latter is about the same as that of the inner canal, but its diameter is much less, probably in most cases not exceeding a micron. Owing to its minuteness it is difficult to determine whether it is furnished with cilia or not, but its appearance in fig. 25*e* seems to indicate that it contains at least a single cilium or flagellum. The transverse canal terminates in the antero-lateral portion of the *ventral glandular portion* of the nephridium (text fig. IV, figs. 25*d*, 25*e*, and 26, *v.g.n.*). This body is very similar to the lateral glandular portion, and will therefore require no further description. It lies just above the lateral nerve cord of that side, and posterior to the middle of the second trunk segment, whereas the lateral glandular portion is situated at precisely the middle of the segment.

The transverse canal serves to link together the two glandular portions of the nephridia, but these are further connected by a large ciliated canal, *the diagonal canal* (text fig. IV, figs. 25*b*, 25*c*, and 26, *d.c.n.*), which arises at the anterior end of the lateral glandular portion and passes diagonally backward to the anterior end of the ventral glandular portion. It enters the latter near the termination of the transverse canal; the two canals in fact being connected with one another at this point.

The duct of the nephridium springs from the ventral glandular portion at the point where the latter is connected with the transverse and diagonal canals (text fig. IV, figs. 25*a-c*, *d.n.*). The duct is here relatively large, but narrows rapidly as it passes cephalad. A short distance from its point of origin it dips downward and becomes buried in the substance of the body wall laterad of the ventral nerve cords, and is recognizable in sections only as a brownish ovoid area in the hypodermis (fig. 5, *d.n.*). It thus pursues a direction cephalad and slightly mesiad until it reaches the middle of the first trunk segment. Here it bends sharply inward (mesiad), widening considerably at the same time, and opens to the exterior at the postero-lateral border of the mouth (text fig. IV). The duct is similar in structure to that of unicellular glands, such as the salivary gland of *Dinophilus*, and appears to be merely a process of one of the cells of the ventral glandu lar portion, the cell wall covering this process serving as the walls of the duct. This duct, as indicated above, is filled with a brownish excretion.

Embedded within the cytoplasm which surround the diagonal and transverse canals are found greenish refringent bodies (figs. 25*c*, 25*d*, and 26*b*, *r.b.*) of an irregular ovoid shape, and similar in general appearance to those seen in the nephridia of the posterior segments. In the nephridium represented in text fig. IV and figs. 25*c* and 25*d* there are two of these, of nearly the same size. In the nephridium represented in figs. 26*a* and 26*b* there are also two subequal refringent bodies, and in addition a densely staining inclusion.

From the foregoing description it is seen that in the first pair of nephridia of *Dinophilus conklini* we have to do with relatively complex and highly differentiated structures. A contemplation of text fig. IV will show, however, that these nephridia are derived from simple nephridia, of the type termed by Hatschek (1888) "protonephridia," like those of the four succeeding pairs, by a growth and differentiation of their component cells, chiefly at two points, namely, those occupied by the glandular bodies. The blind ciliated anterior end is clearly to be recognized as the inner or central end of the simple nephridium, and the canalar plexuses, with their connecting transverse and oblique canals, as its middle part. Obviously one of these connecting canals is of secondary origin and one of primary, corresponding to the original lumen of the primitive nephridium. The size of the diagonal canal, and the fact that its connection with the lateral glandular portion is some distance removed from the union of the latter with the inner canal, speaks in favor of its being the representative of the primitive lumen; the transverse canal would then have to be considered as a sort of short cut for the products of excretion from both the inner canal and the lateral glandular portion of the nephridium. The terminal duct has also evidently undergone modification in that its external opening has been shifted forward to the edge of the mouth.

The function of the glandular bodies with the contained canalar plexuses can only be guessed at. It is at least certain that it is one not performed by the other nephridia. That this function is truly of a glandular nature is indicated by the fact that the ducts are always filled by a homogeneous substance of a brownish color, much resembling mucus in appearance.

The highly differentiated groups of the *Oligochæta* and *Hirudinea* alone appear to exhibit conditions comparable to those seen in the anterior pair of nephridia of *Dinophilus conklini*. A breaking up of the canal to form a plexus is found in the median portion of the nephridium of the leech (Graf, 1898), and also in the *Enchytræidæ* (Bolsius, 1892) and the *Discodrilidæ* (Moore, 1897). Certain nephridia of some members of the *Naidomorpha, Lumbriculidæ* (Vejdovsky, 1884), and *Tubificidæ* (Stolc, 1888) possess on that part of the nephridium just following the funnel an oval swelling of a brown color, and within which the nephridial lumen forms a network. In the case of *Nais,* however, this swelling appears to consist of but a single cell.

Shearer (1906) has recently made a detailed study of the nephridia of *D. tæniatus.* He finds that in their general form and arrangement they correspond to the description given by Harmer (1889*a*). He adds, however, the important fact that the inner end of each nephridium bears a large number of the curious structures discovered by Goodrich, and called by him "solenocytes" (1898). The cilia of the solenocytes traverse the length of the nephridium, giving it the appearance of being lined with cilia. As to the presence or absence of these structures in the posterior four pairs of nephridia of *D. conklini,* I am not able to decide with the material at hand. It seems, however, quite certain that solenocytes are not present in the nephridia of the first pair. Here the images afforded by my material are quite clear, the finer structure in the most favorable instances being quite well preserved, and affording a good basis for decision. If present at all the solenocytes should be found cephalad of what I have termed the "anterior canal," and within the strand of protoplasm in which this canal runs (see fig. 26*a* and text fig. IV). This portion of the protoplasmic strand, however, appears uniform in structure, and contains nothing which would indicate the presence of solenocytes.

Amœboid Cells.—In many series of sections there appear large cells of irregular form, situated in the cavity of the head and in the body cavity of the neck region, dorsad and laterad to the anterior portion of the œsophagus (figs. 3 and 4, *am.c.*). Their cytoplasm is coarsely granular in appearance, and is frequently seen to contain densely staining inclusions of various shapes and frequently of large size. The nuclei of these cells are vesicular and contain but little chromatin, outside of the large spherical karyosome. In at least one instance a number of these cells were found in an evident state of degeneration, some within the cavity of the head, others buried in its ventral hypodermis. This latter circumstance, together with the varying location of these cells within the limits indicated, and the fact that their shape conforms to the outline of the adjacent tissues, strongly indicates that their nature is amœboid. Their origin is obscure; but their close resemblance in size and staining reaction to many of the cells composing the lateral walls of the ascending limb of the œsophagus, in addition to the fact that, in those individuals in which these amœboid cells occur, they are always found in the neck region in a normal condition, seems to point to the œsophagus as their place of origin.

The function of these cells is somewhat problematical. Their amœboid and phagocyte-like appearance, the frequent occurrence of inclusions, and their degeneration within the ectoderm near the exterior, point strongly to the conclusion that they perform the function of phagocytes. This conclusion attains a considerable degree of probability in the light of the researches of Schaeppi (1894) and Graf (1898) on polychætous annelids and leeches respectively. In representatives of both these groups there are found in the body cavity amœboid cells ("Chlorogogen," "Excretophores"), whose function is to ingest and remove waste matters. Moreover, Graf found that in the leech these cells sometimes degenerated in the epidermis. There seems, therefore, much reason to believe that the amœboid cells in *Dinophilus* are also "excretophores."

6. *Sex Organs.*

Ovary.—The ovary in its position and general structure resembles that of *Dinophilus apatris* and *Dinophilus gyrociliatus,* as described by Korschelt (1882) and Repiachoff (1886) respectively. It lies on the ventral side of the alimentary canal, occupying the concavity formed by the junction of the stomach and intestine, and commonly fills up this space and crowds the intestine towards the dorsal side. The ovary consists essentially of three parts: the oögonia; the oöcytes; and the peritoneal sac enveloping the whole.

The oögonia form a pyriform mass of closely packed cells (fig. 21, *oög.*), its smaller end directed caudad. The apex of the oögonial mass is formed of the younger cells, which are still in a state of multiplication. In fig. 21 a zone of dividing cells is seen extending across this portion of the ovary. Beyond this zone the oögonia may be seen to increase gradually in size toward the anterior end of the oögonial mass, where the oögonia, having completed their growth, become oöcytes. The manner of formation of the large ova which are destined to form the female individuals, by the fusion together of several oögonia, was first noted by Schimkewitsch (1895), and has been more fully described by Conklin (1906) for the form under discussion, and by von Malsen (1906) for *D. apatris,* and will not be dwelt upon here. The cytoplasm of the oögonia is finely granular, and stains more or less densely, doubtless owing to the presence of small yolk granules. The nuclei possess the general character of those of the tissue cells, being vesicular, and containing a large chromatin nucleolus.

The oöcytes, or ovarian eggs, constitute the greater part of the ovary, and form a closely packed mass entirely filling up the remainder of the space below the intestine, which lies close to the dorsal body wall. The oögonial mass is commonly crowded to one side of the oöcytes, thus lying laterad and often somewhat ventrad of the latter. In some cases, indeed, a large oöcyte, apparently full grown, is found in the posterior portion of the ovarian chamber, caudad of the oögonia. The mature female ova are in the neighborhood of 100 μ in diameter, closely approximating that of the body of the parent. The diameter of the ova destined to form males is much smaller, *i.e.*, about 30 μ.

The first maturation division, as least as far as the metaphase, occurs within the ovary, and has been observed by both Conklin (1906) and myself. Von Malsen (1906) states that in one instance only did he find maturation spindles within the ovarian chamber. It is curious to note that in those preparations which showed the karyokinetic figures, all of the mature oöcytes appear to be dividing simultaneously and at the same rate, since all of the spindles were in the same phase, namely, the metaphase. The probable explanation of this phenomenon is that, as in *Ophryotrocha* (Korschelt, 1903), the oöcytes remain at this stage of division until penetrated by the sperm. All of these dividing ova displayed a well-marked peri-vitelline layer, which stains strongly in Meyer's mucicarmine. This layer, however, does not extend completely around the ova, but is seen only on their free surfaces, its formation being in some way prevented by contact with other ova.

The peritoneal investment of the ovary consists of an extremely delicate epithelium which encloses the oögonia and oöcytes as in a bag, and is attached posteriorly to the apex of the pyriform oögonial mass (see figs. 7 and 21, *per.*). From the outer surface of the peritoneum thin strands of protoplasm are here and there given off to the neighboring alimentary canal and body wall. The existence of this epithelial covering was for a long time a matter of much doubt in my mind, and it is only after careful study of sections of the best preserved material that I have arrived at the conclusion stated above. In some cases the peritoneum is well marked and easily demonstrated, as in fig. 7; in others, as in the section represented by fig. 21, the peritoneum is exceedingly tenuous. That it is a true epithelial layer is shown by the presence in it of small nuclei. Von Malsen (1906) also observed this layer, but saw only that portion of it which lies ventrad of the ovary, the dorsal portion being concealed by the close apposition of the ovary and the alimentary canal. For this reason he interprets it as a portion of the splanchnopleure, apparently assuming with Repiachoff (1886) the presence of a continuous peritoneal lining throughout the body cavity. The ovary would then, according to von Malsen, lie *outside* of the cœlom, between the alimentary canal and the peritoneum.

The presence of a definite peritoneal investment surrounding the ovary of *D. conklini* is in accord with the observations of both Harmer (1889*a*) and Schimkewitsch (1895). In the two forms investigated by these authors—*D. tæniatus* and *D. vorticoides*—the gonads consist of long paired sacs, from the walls of which arise the sexual products. These sacs, moreover, in *D. vorticoides*, according to the researches of Schimkewitsch, arise from the paired mesoderm bands. There can, therefore, be little doubt that the gonads with their enclosed cavities, as Meyer (1901) has also pointed out, are homologous with the peritoneum and cœlom of the *Annelida*.

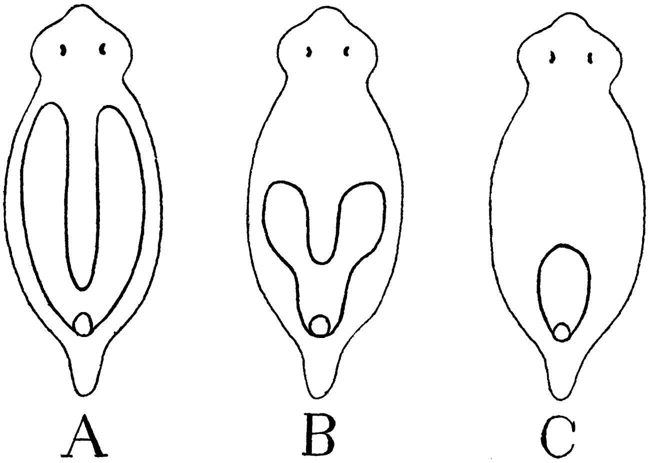

Fig. V.—Diagrams illustrating the reduction of the sex glands in *Dinophilus*, as represented by A, *D. vorticoides* and *tæniatus;* B, *D. gigas;* C, *D. conklini.*

It is evident, however, that, in the light of this interpretation, the cœlom of *D. conklini* is greatly reduced, as compared with those species mentioned above. This reduction becomes more comprehensible when the condition in *D. gigas* is taken into consideration. The sex gland of this species is, according to Weldon (1886), Y-shaped, the unpaired limb lying posterior, the two anterior limbs extending forward a short distance under the hinder portion of the stomach. Weldon describes no peritoneal investment of the sex glands, it is true, but this might easily have been overlooked, inasmuch as it is probably very thin. Indeed, in the anterior portion of the testes of *D. metameroides*, Schimkewitsch (1895) states that the peritoneum becomes reduced to a mere *membrana propria*. For this reason, and because of the occurrence of a peritoneum enclosing the sex products in at least two other species, it is not unwarrantable, to say the least, to assume its presence in *D. gigas*. The condition obtaining in this species would then be almost precisely intermediate between that found in *D. vorticoides* and *tæniatus*, on the one hand, and *D. conklini* (and probably also *apatris* and *gyrociliatus*) on the other. In other words, there has been within the *Dinophilidæ* a progressive reduction in the shape and extent of the sex glands, and also of the cœlom, represented by the cavity within them; this reduction beginning at their anterior ends, and its stages exemplified by the three species named. These are represented diagrammatically by text figs. V, A, B, and C. In the first stage, (A), represented by *D. vorticoides* and *tæniatus*, the sex glands are paired, extend throughout the greater portion of the trunk, and are united only at their posterior ends. In the second, (B), represented by *D. gigas*, the paired portions are much shortened, while the unpaired median part, which joins the former, has increased somewhat in length. In the third and last stage, represented by *D. conklini*, the lateral paired portions have disappeared altogether, leaving only the posterior unpaired part. That the paired condition, represented in A, is probably the more primitive one need scarcely be pointed out; the unpaired is therefore specialized. It is also to be noted in this connection that those species possessing the unpaired sex gland are also sexually dimorphic.

In *D. vorticoides*, *tæniatus*, and *gigas* the reproductive cells appear to be produced directly from the wall of the sex glands (cœlomic epithelium) by transformation of its cells. Moreover, the production of germ cells appears not to be definitely localized, but to take place throughout the length of the glands. The condition in *D. conklini* is evidently quite different. Here a circumscribed portion of the cœlomic epithelium is, as in the higher *Vermes*, differentiated to form a well-defined gonad, in the shape of the pyriform mass of oögonia.

Korschelt (1882) was of the opinion that the germ cells arose in the walls of the alimentary canal. Von Malsen (1906) has recently thought to have found confirmation of this view and has described and figured the germ cells as arising in the ventral wall of the stomach, and migrating thence by amœboid movement into the oögonial mass at some distance from its posterior end. This is certainly an error and, I believe, based on defective fixation. Von Malsen states that in his studies on the oögenesis of *Dinophilus* he relied chiefly on sections made from material fixed in Kleinenberg's picro-sulphuric. This fixative, as I have already stated in the section on technique, is unreliable, at least for the study of the morphology of *Dinophilus conklini.* Sections made from material fixed in this fluid yield images which could easily lead one to believe in a close connection between the ovary and the alimentary canal, and at the outset I was myself inclined to such a view. Better preserved material, however, has demonstrated conclusively that no such close connection exists. Moreover, in *D. conklini* the oögonial mass is commonly separated from the alimentary canal by the large oöcytes, thus effectively barring any communication between the oögonia and the alimentary canal.

A median generative pore—sperm duct or oviduct—situated on the ventral side, near the posterior end of the body, has been seen in three species of *Dinophilus,* namely, *D. vorticoides* (Schimkewitsch, 1895), *D. tœniatus* (Harmer, 1889*a*), and *D. apatris* (Korschelt, 1882). In the last-named species the oviduct was seen during life, but was not found in preserved material. It is with regret I confess that so far I have been unable to demonstrate an oviduct in *D. conklini,* although a careful search for it has been made. That it exists there is scarcely the slightest doubt. Weldon (1886) was also unable to discover the genital opening in *D. gigas,* and has assumed that a rupture of the body wall occurs on the maturing of the genital products, allowing the latter to escape; this occurrence being accompanied by the degeneration and death of the animals. Whether this be true of *D. gigas* or not, it is probably not true of *D. conklini*—although this species, as does *D. gigas,* rather suddenly disappears on the arrival of warm weather—since von Malsen (1906) has shown that in *D. apatris,* a species very similar to *D. conklini,* the egg-laying period is one of considerable extent.

7. *Discussion and Conclusions.*

Metamerism.—In *Dinophilus conklini,* as in other members of the group, there is a distinct and well-marked metamerism. This is expressed by the body wall in its external divisions, its ciliated rings, and its mucous glands; by the nervous system in its pairs of trunk ganglia, and by the nephridia in their arrangement in five pairs. The metamerism is that of the annelids, and expressed in the same terms, but with an important exception: in *Dinophilus* it is apparently not manifested in the sex organs, the homologues of those organs and tissues which are, in the annelids, the products of the mesoderm bands.

The number of segments, as indicated by the body wall in its external divisions and ciliated rings, does not agree with that indicated by the other metamerically arranged parts. The former—the trunk segments as delimited by constrictions and their ciliated bands—indicate six trunk segments, while the latter, namely, the mucous glands, the nerve ganglia and the nephridia, testify to only five. Examination of text fig. III and fig. 1 will show that the segment not represented by ganglia or mucous glands is the first postoral. It may be added that this segment is also not represented by the nephridia, since, although the first pair of nephridia do actually extend into this segment, the greater part of these organs lie in the segment following, and obviously belong to the latter. That division of the trunk, then, immediately following the neck and bearing the first band of cilia is evidently not a true metamere, but is to be interpreted as a minor annulus, a subdivision of a metamere having occurred, as in all leeches and in some *Oligochæta* and *Polychæta.* The next succeeding annulus, the second, is clearly the corresponding major annulus, and the two together compose the first trunk metamere. The development of an additional annulus in this region is probably to be traced to the demand for greater room on the part of those structures which lie within the first trunk metamere, namely, the proboscis, a relatively large organ, the first pair of nephridia and the first pair of trunk ganglia; the two latter much exceeding in size those of the succeeding segments.

Five trunk metameres are also present in *D. tæniatus* (Harmer, 1889*a*) and in *D. vorticoides* (Schimkewitsch, 1895), as indicated by the number of the trunk ganglia and of the nephridia. Meyer (1886) shows five pairs of nephridia also in his figure of *D. gyrociliatus;* the number of trunk ganglia, is, however, unknown, since the nervous system of this species has so far not been carefully investigated. This species (*gyrociliatus*), as judged by Meyer's figure, displays a condition precisely similar to that obtaining in *D. conklini,* since there apperas to be present six trunk segments, in the second of which the first pair of nephridia are situated. The first trunk metamere is therefore evidently also composed of two annuli, of which the posterior is the major. In *D. vorticoides* (Schimkewitsch, 1895) one of the trunk metameres appears also to have been subdivided into annuli, since the trunk bears twelve double rings of cilia. As to the particular metamere which has subdivided, it is impossible to conclude from Schimkewitsch's figures, although it seems probable that it is one of those in the posterior part of the body. From the evidence at hand it is seen that four of the nine species of *Dinophilus* are composed of six segments (metameres), counting the head, and this raises the question as to whether this number is characteristic of the group; the answer to which must necessarily be found in further research.

Cephalization.—Among the evidences of specialization exhibited by *Dinophilus conklini* is a well-defined tendency to cephalization on the part of the nervous system and the nephridia. A glance at fig. 1 will serve to show that this is true of the nervous system, especially as regards the number of nerve cells. That a like tendency is exhibited by the nephridia also will be plain on considering the great size and complexity of the first pair of nephridia as compared with the succeeding four.

Relationships.—The systematic position and affinities of *Dinophilus* have been long debated, and is a question concerning which every one who has investigated this form has expressed an opinion. In a previous paper on the embryology of *Dinophilus* (1904*a*), I have given a brief historical sketch of the various views expressed by different authors on this subject, so it need only to be referred to here. Broadly speaking, these views may be divided into three classes, according as they regard *Dinophilus* as most nearly related to the *Turbellaria,* to the *Rotatoria,* or to the *Annelida.*

In respect to the morphological evidence on which the first of these views is based, Lang (1884) has summed this up so concisely and completely that I cannot do better than to quote his words in full:

"I believe that Korschelt[5] is on the wrong track; there are no *Turbellaria* with an anus, none with ciliated rings. The pharanx of *Dinophilus* has nothing in common with the pharanx of the *Turbellaria.* None of the *Turbellaria* have a straight alimentary canal so much differentiated. The sex organs are constructed differently in the two groups; in the *Turbellaria* complicated ducts are always present. The sexual dimorphism removes *Dinophilus* from the *Turbellaria,* as well as the well-developed body cavity. I do not believe that, as Korschelt supposes, the ova arise from the epithelium of the alimentary canal. They indeed lie in the body cavity close to the alimentary canal, but I am strongly of the opinion that a fine endothelium is here present, from which they develop. Everyone knows how difficult endothelium is to recognize. The distinction between *Dinophilus* and the *Turbellaria* is much greater, if it is compared to the larvæ of the latter. Yet the resemblance should be greater if, as Korschelt supposes, *Dinophilus* be a primitive Turbellarian form."

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[5] Lang here refers to Korschelt's earlier view (1882). Korschelt has since expressed the opinion that *Dinophilus* is closely allied to the annelids

The weight of the evidence furnished by our present knowledge of the morphology and embryology of the annelids, as well as that of *Dinophilus,* is, I think, heavily in favor of a close relationship of the latter with the annelids. There is scarcely a character in the structure of *Dinophilus* which is not held in common with some member of that group. The general external form, including the distribution of the cilia and the caudal appendage, are found in several annelid larvæ, such as *Harpochœta* (Korschelt, 1893); the ciliated rings may persist to maturity, as in *Ophyrotrocha* (Korschelt, 1893) and *Nerilla* (Pereyaslawzewa, 1896), as well as in *Protodrilus* (Hatschek, 1880). The metamerism is also like that of the annelids, expressed by the same organs—with the exception of those arising from the mesoderm bands—and developed in the same manner, as the investigations of Schimkewitsch (1895) and myself (1904*a*) have shown. The nephridia are precisely like those seen in many annelid larvæ. Moreover, Shearer (1906) has recently found that the nephridia of *D. tæniatus* possess the curious structures termed by Goodrich (1898) "solenocytes," and found by him characteristic of many members of the *Polychœta.* The type of the nervous system of *Dinophilus* is unquestionably the embryonic annelid type; even its distinctive features, such as its epithelial position and the wide separation of the two halves of the ventral cord, are found not only in larval stages, but also in adult stages of several members of the *Annelida.* The preoral commissure of *D. conklini* can also, I think, only be satisfactorily explained by deriving it from the nerve ring of the trochophore larva. The alimentary canal is, in its main features, strictly comparable to that of the annelids; while the proboscis, in its general structure, is like that of many *Polychœta,* as, for example, the *Eunicidœ* (Lang, 1891).

A possible relationship with the *Rotatoria* has been pointed out by several investigators; of these probably Schimkewitsch (1895) has stated the case for the rotifers most clearly. After a very fair presentation of the claims of *Dinophilus* to a place among the annelids, he says:

"Ohne Zweifel sind auch einige Züge vorhanden, die *Dinophilus* mit den Rotatorien verbinden: die furchung des Eies, die Anwesenheit des Schwanzanhanges, der mit dem Fusse der Rotatorien übereinstimmt, der geschlechtliche Dimorphismus; man muss auch gestehen, dass im Baue des Nervensystems und der Hauptmusculatur der Rotatorien die Tendenz zur Erwerbung der Metamerie bemerkt werden kann: bei *Dinophilus* aber erstreckt sich diese Tendenz auch auf das Mesoderm und die Excretionsorgane. Auch bei den Rotatorien erscheinen, wie bei *Dinophilus* die Genitalhöhlen als einzige Homologa des Cöeloms."

According to this view the metamerism, as well as many other annelidan features, would have to be regarded as having arisen independently. From this standpoint *Dinophilus* would, so far as its resemblance to annelids is concerned, be a good example of convergence. In regard to the points of resemblance which Schimkewitsch has pointed out: the segmentation of the egg has been shown to be strictly annelidan in its type. The caudal appendage of *Dinophilus* much more closely resembles that of some polytrochal annelid larvæ than the foot of the *Rotatoria.* The sexual dimorphism quite clearly arose within the group, and is one which is found in other groups than the rotifers. The condition of the sex organs in the less specialized members of the *Dinophilidæ* (*e.g.*, *D. vorticoides*) Meyer (1901) regards as representative of the primitive condition of the cœlomesoblast in the annelids, and one which is quite different from that found in rotifers, since the unpaired condition found in *D. conklini* is evidently a derived one. Moreover, the opinion is widely held that the *Rotatoria* constitute a highly specialized group of somewhat uncertain affinities, since much doubt has been thrown on its formerly assumed close relation to the trochophore. In short, when the various morphological characters can be duplicated within the annelids, or accounted for by derivation from that ancient and primitive group, it seems superfluous to suppose that they have arisen independently, and to derive *Dinophilus* from such a comparatively specialized group as the *Rotatoria.*

Dinophilus has also been often compared to the trochophore larva of annelids, but this comparison is somewhat inexact, if the term trochophore is employed in the strictest sense. The resemblance is rather to that intermediate stage in the metamorphosis represented by some larvæ of the polytrochal type. The head of *Dinophilus* is, for example, in no way comparable to the inflated cephalic vesicle of the typical trochophore; the trunk with its various organs is distinctly metameric, and therefore to be compared with the trunk of the worm. On the other hand, such features as the ciliated bands, particularly those preoral in position, the ventral ciliated tract, and the preoral commissure, have obviously been derived from the trochophore stage. On the whole, *Dinophilus* can best be considered as a very young polychæte worm, retaining some of its larval features, with setæ and parapodia undeveloped, and whose peritoneum and cœlom have been transformed into a generative organ.

8. *Summary.*

External Form.—The head of the female (text fig. I) is bluntly conical in front and tapers rapidly behind to a well-defined neck. A pair of red kidney-shaped eyes are borne on the dorsal surface of the head. On its anterior surface are two long sense hairs, symmetrically placed, and a number of smaller ones. A group of small sense hairs is also present on its dorsal surface. The body is cigar-shaped, and divided by constrictions into six segments, each of which bears a single band of cilia. A circumanal band of cilia is also present, but is interrupted on the dorsal surface. The head bears two rings of cilia, one in front of the eyes, and one behind them, the latter band encircling the head at its greatest diameter. Both of these bands are interrupted by a dorsal gap. The anterior cephalic bands bend backward between the eyes. On each side of the head, behind the second cephalic ring, is a shallow ciliated groove which runs ventrad to the lateral borders of the mouth. A strip of cilia clothes the ventral surface of the animal from the anterior tip of the head to the end of the caudal appendage. The males (text fig. II) are minute in size, short cylindrical in form, and slightly constricted in the middle. A circular band of cilia is borne at the anterior end, and a ciliated strip covers the ventral surface. A conical penis is found near the posterior end of the body.

Body Wall.—The body wall is composed of a one-layered hypodermis, covered on the exterior by a thin cuticle. It is thin in the intersegmental regions, thick in the intrasegmental. A ventral thickened area extends the entire length of the animal.

Gland Cells.—The body wall contains glands of three types. The glands of the first type are mucous in character, scarce, and confined to the ventral surface. Those of the second are also mucous glands, long-pyriform in shape, metameric and symmetrical in their distribution, and fairly constant in number (text fig. III). The glands of the third type are non-mucous, very long-pyriform in shape, and found principally near the middle of the trunk segments, and on the head.

Muscles.—The muscles comprise two sets, longitudinal and transverse. The former are divided into three pairs. One pair lies close together on the ventral side of the trunk, and traverses the latter from the anus to the posterior side of the mouth. The second pair are ventro-lateral in position and run from the anus to the anterior portion of the head, penetrating the brain in their course. The third pair is dorso-lateral in position and also runs from the anus to the head. Fibres from the second pair (ventro-lateral muscles) meet and cross in the head cavity. The second set of muscles comprises muscle fibres which traverse the head cavity in a dorso-ventral direction, from side to side, and also obliquely.

NERVOUS SYSTEM.—*Central Nervous System.*—The central nervous system (fig. 1) includes a simple brain, in close contact with the hypodermis, circumœsophageal connectives, and a pair of ventral nerve cords. The latter traverse the whole length of the trunk and are throughout embedded in the hypodermis. They are connected by transverse commissures, three being present in the second trunk segment, and two in each of the three following. A preoral transverse commissure is also present, which appears to be the homologue of the ventral portion of the nerve-ring of the trochophore larva of the annelids. Ganglion cells are present, also embedded in the hypodermis, and arranged to form four well-defined pairs of ganglia. A fifth is possibly indicated. Large nerve-trunks are given off from the circumœsophageal commissure to the œsophagus and the ventro-lateral muscles.

Sense Organs.—The eyes consist each of a bilobed lens and a pigment cup. The inner end of the latter is buried in the outer surface of the brain. The large sense hairs on the anterior surface of the head are connected with the brain by sensory neurons. Problematical sense organs are found on the sides of the neck.

ALIMENTARY CANAL.—The mouth is triradiate and is situated on the ventral side of the head. It opens into an œsophagus which passes upward, then backward for a short distance, to empty into a capacious stomach which fills the body cavity in the third and fourth trunk segments. Near the anterior border of the fifth trunk segment the stomach joins the intestine, which passes in an almost straight course to the anus. The latter is situated dorsad of the caudal appendage. The alimentary canal is lined throughout with long cilia. The œsophagus is provided with a large proboscis (fig. 23, *pro.*). The latter is in shape ovoid, flattened dorso-ventrally, and is situated just within the mouth, in an involution of the posterior wall of the ascending limb of the œsophagus, and is attached to the œsophageal wall at the bottom of the involution. The proboscis is made up of flat cells arranged like coins in a pile, and separated by chitonized partitions. On each side of every partition is a layer of muscular fibres. The function of the latter appears to be that of elongating the proboscis. This organ is moreover provided with a set of extrinsic muscles.

Glands.—The œsophagus is provided with so-called salivary glands, which consist of two sets of unicellular glands, one on each side of the œsophagus. The ducts from these glands pass forward separately to empty into the anterior part of the œsophagus. Unicellular digestive glands are found in the walls of the stomach. In the dorsal part of the cavity of the head there are two groups of large pyriform glands, which send down slender ducts to the ventral surface of the head. The function of these glands is unknown.

EXCRETORY ORGANS.—*Nephridia.*—Five pairs of nephridia are present. The nephridia belonging to the posterior four pairs are simple tubes of delicate structure, with a blind inner end. The anterior pair are relatively large and complex organs (text fig. IV), consisting of an anterior canal, representing the blind inner end of the simple type of nephridium; two large glandular bodies, connected with transverse and diagonal canals, and a long duct opening on the posterior border of the mouth.

Amœboid Cells.—Large amœboid cells are found in the anterior part of the body cavity, and also in the head cavity. Their function is probably phagocytic.

SEX ORGANS.—*Ovary.*—The ovary lies on the ventral side of the alimentary canal, in the angle formed by the junction of the stomach and intestine. It consists essentially of a very thin peritoneal sac, to the posterior portion of which is attached a pyriform mass of oögonia, forming a gonad, which lies inside of the sac. The peritoneal sac is usually distended with ova, some of which were seen undergoing the first maturation division. No oviduct was found.

CONCLUSIONS.—*Metamerism.*—A well-marked metamerism is present, expressed by the body wall and its mucous glands, the nephridia, and the nervous system. The presence of five trunk metameres is indicated, the most anterior of which is subdivided into two annuli.

Cephalization.—A marked tendency to cephalization is shown by the nephridia and the nervous system.

Relationships.—The morphological evidence indicates close affinities with the chaetopod annelids.

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Explanation of Plates XII and XIII.

The figures have been drawn by the aid of the camera lucida at the level of the table, under Zeiss homo. imm. $\frac{1}{12}$, using the oculars 2 and 4 of Zeiss, and 3 and 5 of Leitz. The magnification, in diameters, of each of these combinations was determined, and the particular magnification employed in each figure is indicated after the description of that figure.

Reference Letters.

am.c., amœboid cell.
br., brain.
br.com., transverse commissure of brain.
c.com., circumœsophageal commissure.
c.e.n., central (anterior) end of nephridium.
c.g., cilia of ciliated groove.
c.gl., cephalic gland.
c.gl.d., duct of cephalic gland.
c.r. 1–9, 1st to 9th ciliated rings.
cut., cuticle.
d.c.n., diagonal canal of nephridium of 1st pair.
d.l.m., dorso-lateral longitudinal muscle.
d.n., duct of nephridium of 1st pair.
d.v.m., dorso-ventral muscle of head.
e., eye.
g.c., ganglion cells.
g.gl., gastric gland.
g. 2–5, ganglia of the 2d to the 5th trunk segments.
gl. 1–3, hypodermal glands of the 1st to the 3d type.
hyp., hypodermis.
i.c.n., inner (anterior) canal of nephridium of 1st pair.
i.l., inner lip.
int., intestine.
int.m., muscle encircling terminal portion of intestine—sphincter ani.
l., lens of eye.
l.g.n., lateral glandular portion of nephridium of 1st pair.
l.m.c., transverse muscles of head.
l.m.f., longitudinal muscle fibres.
l.m.i., insertion of longitudinal muscles.
l.n., lateral nerve cord.
m., mouth.
mes., mesenchymatous tissue.
m.n., nerve to ventro-lateral longitudinal muscle.
n., nucleus.
n.f., nerve fibres.
np., neuropil.
œs., œsophagus.
œs.m., œsophageal muscles.
œs.n., œsophageal nerve.
o.l., outer lip.
ooc., oöcytes.
oog., oögonia.
p.c., pigment of eye.
per., peritoneum.
pr.com., preoral commissure.
pro. 1, anterior epithelial portion of proboscis.
pro. 2, posterior muscular portion of proboscis.
pro.f., flexor of proboscis.
pro.l., levator of proboscis.
pro.pr., protractor of proboscis.
pro.r., retractor of proboscis.
r.b., refringent body.
s.gl., salivary glands.
s.gl.d., duct of salivary glands.
st., stomach.
st.w., stomach wall.
t.c.n., transverse canal of nephridium of 1st pair.
t.cil., tactile cilia.
t.com., transverse commissure.
v.g.n., ventral glandular portion of nephridium of 1st pair.
v.l.m. 1, median ventral longitudinal muscle.
v.l.m. 2, ventro-lateral longitudinal muscle.

Plate XII, Fig. 1.—The nervous system, slightly schematized, and represented as seen from the dorsal side. Reconstructed from a series of 102 sections of a single individual. The outlines of the body, the mouth, and the ciliated bands are also represented. × 450.

Fig. 2.—Cross section through the brain, showing the neuropil, ganglion cells, and eyes. × 665.

Fig. 3.—Cross section through the anterior portion of the mouth, showing the openings of the ducts of the salivary glands, the œsophageal muscles, the œsophageal nerves, and the longitudinal muscles. × 665.

Fig. 4.—Cross section through the posterior portion of the mouth, showing the œsophagus, the proboscis, and the ducts of the salivary glands. × 665.

Fig. 5.—Cross section through the trunk, just posterior to the mouth, showing the salivary glands, the muscle-nerves, besides the features represented in the preceding figure. × 665.

Fig. 6.—Cross section through the trunk, taken at the level of the 3d trunk segment, showing the stomach, the longitudinal muscles, and the lateral nerve cords. × 665.

Fig. 7.—Cross section through the posterior portion of the trunk, at the level of the anterior half of the 6th trunk segment, showing the intestine, the ovary, and the peritoneum enveloping it. × 665.

Fig. 8.—Cross section through the posterior end of the trunk, just anterior to the anus, showing the hypodermal glands on the dorsal side, and the intestine with a sphincter muscle encircling it. × 665.

Fig. 9.—Cross section through the ventral hypodermis in the posterior portion of the 3d trunk segment, and passing through the posterior commissure of that segment. Ganglion cells and a portion of a nephridium are also shown. × 665.

Fig. 10.—The eye, from a coronal section, showing the bilobed lens, the pigment cup, and the adjacent ganglion cells of the brain. Flemming's fluid. × 1115.

Fig. 11.—Problematical sense organ, also insertion of the œsophageal muscles on the hypodermis. Corrosive-acetic. × 1115.

Fig. 12.—Portion of a coronal section through the head, showing one of the two tufts of tactile cilia borne on the anterior surface of the latter, and the connection of the cilia-bearing cells with the ganglion cells of the brain. Flemming's fluid. × 1115.

Fig. 13.—Two muscle fibres from one of the diagonal muscles of the head, showing the nucleus and cell body attached to the fibres. × 1115.

Fig. 14.—Section through a portion of the ventral hypodermis, showing ciliated and non-ciliated cells, the cuticle, and also the median ventral longitudinal muscle fibres. Flemming's fluid. × 1115.

Figs. 15–17. Hypodermal glands of the first, second and third types, respectively. × 1115.

Fig. 18.—Four glands from the dorsal hypodermis of the posterior end of the trunk. Three of them are non-mucous glands (*gl.* 3.); the remaining one (*gl. 2.*) contains mucus. × 1115.

Plate XIII, Fig. 19.—Coronal section through head, showing the brain and the insertion of the longitudinal muscles. × 665.

Fig. 20.—Coronal section through head, taken at a lower level than the figure preceding, showing the transverse commissure of the brain, the orign of the circumœsophageal commissures, and the preoral commissure. × 665.

Fig. 21.—Ovary, from a sagittal section. The ventral hypodermis is also represented, as well as the outlines of the stomach and intestinal walls. × 665.

Fig. 22.—Cephalic gland, drawn from two sagittal sections. The outlines of the neuropil, of ganglion cells, and of a hypodermal cell are also indicated. Flemming's fluid. × 665.

Fig. 23.—Sagittal section through the head and anterior portion of the trunk, showing the brain, the preoral transverse commissure, the mouth, the œsophagus, the proboscis, and muscle insertions. × 665.

Fig. 24.—Portion of the lateral body-wall of the 3d trunk segment, showing the inner end of the right member of the second pair of nephridia. Corrosive-acetic. × 1115.

Fig. 25*a*–*e*.—Five consecutive cross sections through the left nephridium of the first pair; fig. 25*a* being the most anterior of the series. Corrosive-acetic. × 1115.

Figs. 26*a*–*b*.—Two consecutive coronal sections through one of the nephridia of the first pair; fig. 26*a* lying uppermost. Corrosive-acetic. × 1115.

Fig. 27.—Three cells of the ciliated band of the first trunk segment, from a tangential section. Flemming's fluid. × 1115.

Fig. 28.—The second cephalic ciliated band and the ciliated groove, from a tangential section. × 1115.

Fig. 29.—The ventral hypodermis, showing ciliated and non-ciliated cells, from a horizontal section. × 665.

Fig. 30.—Cross section through the proboscis, showing two layers of the intrinsic muscle fibres. Flemming's fluid. × 665.

Figs. 31 and 32.—Degenerating cells of the œsophageal wall. Corrosive-acetic. × 1115.

Fig. 33.—A spherical body with its accompanying nucleus, from the stomach wall. Corrosive-acetic. × 1115.

Fig. 34.—Digestive gland, from the stomach wall. Corrosive-acetic. × 1115.

Fig. 35.—Cells from the stomach wall. Flemming's fluid. × 665.

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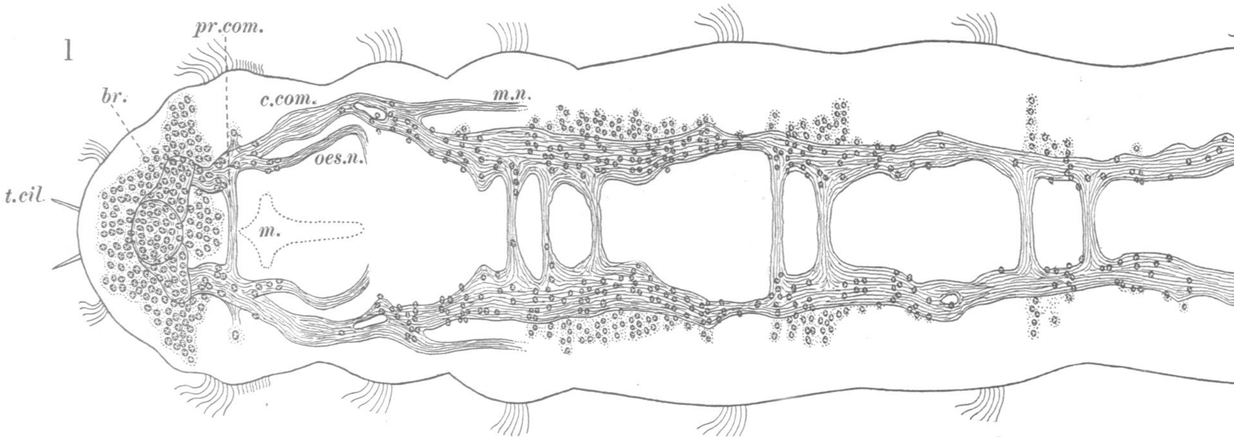
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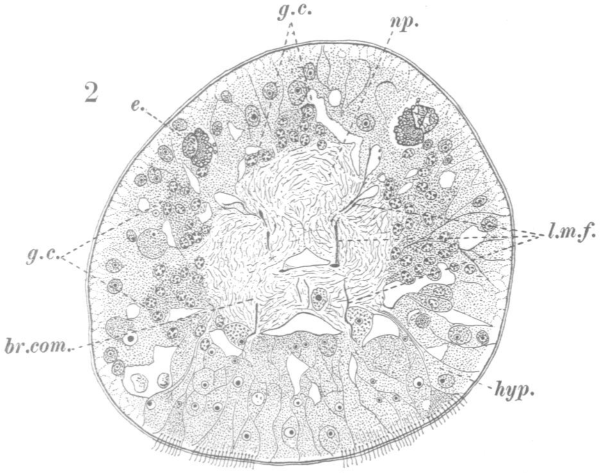
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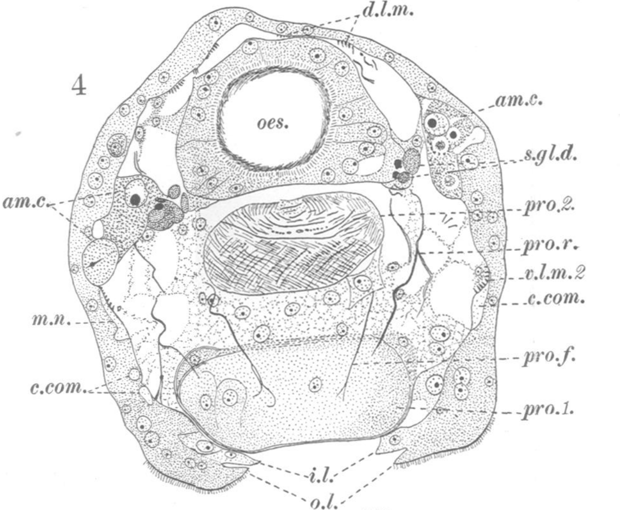
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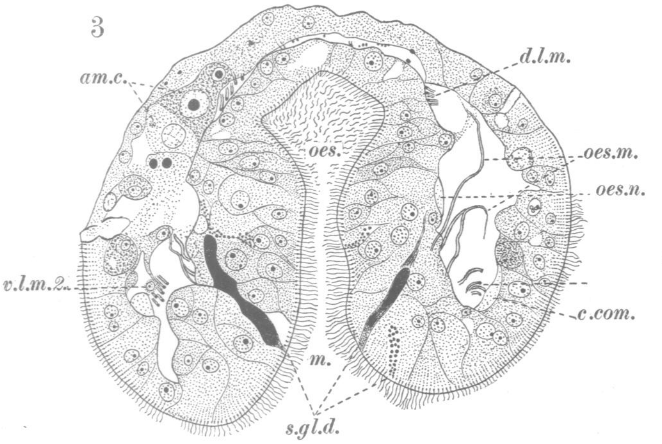
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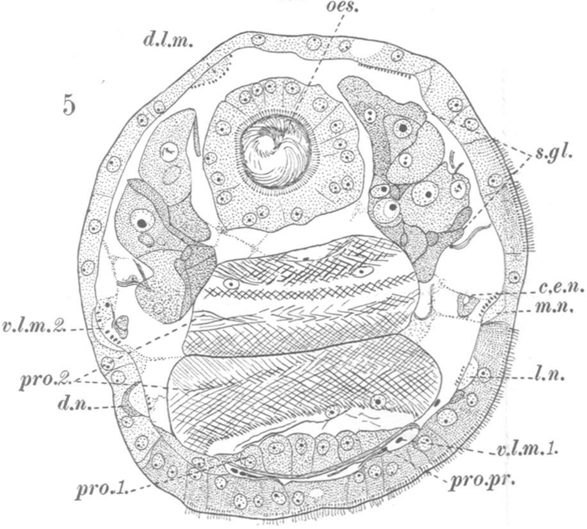
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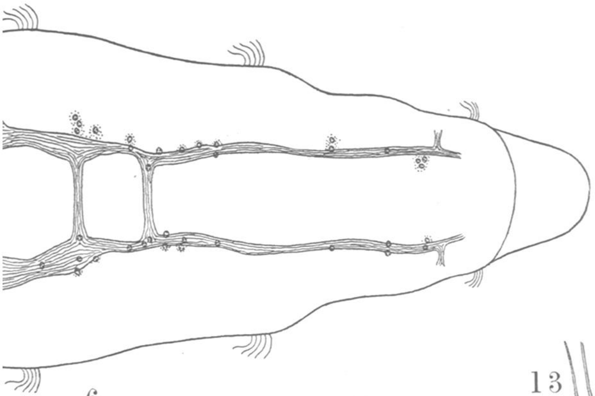

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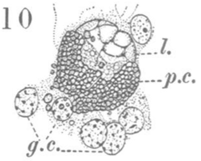

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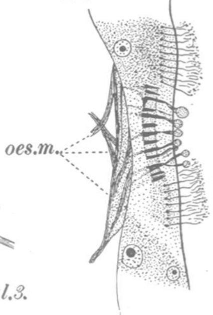

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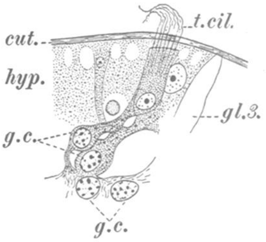

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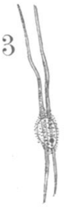

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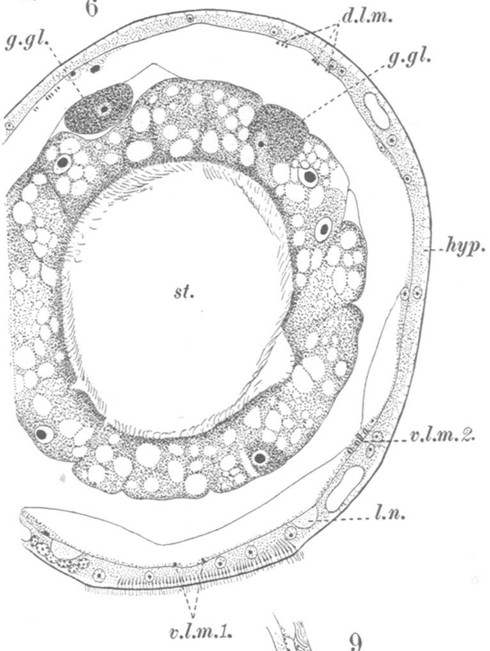

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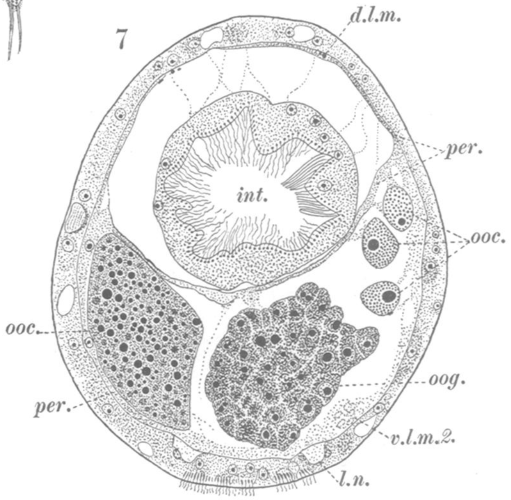

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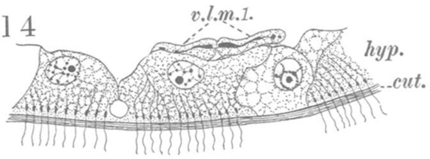

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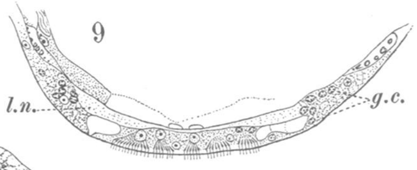

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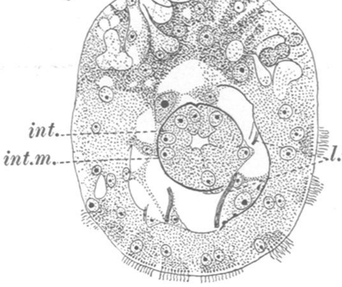

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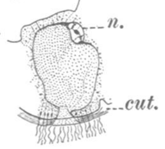

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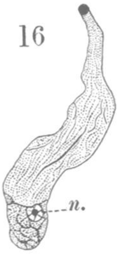

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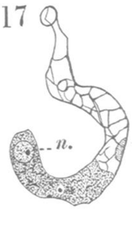

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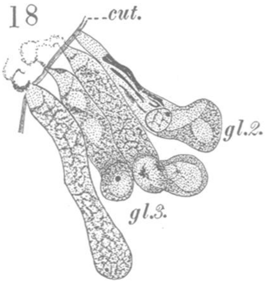

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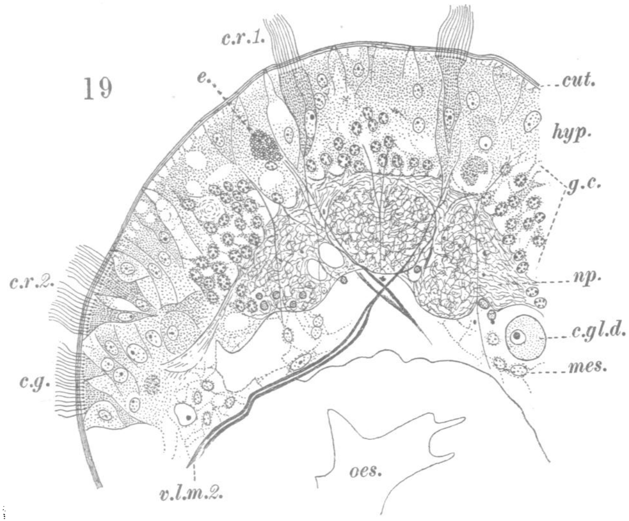

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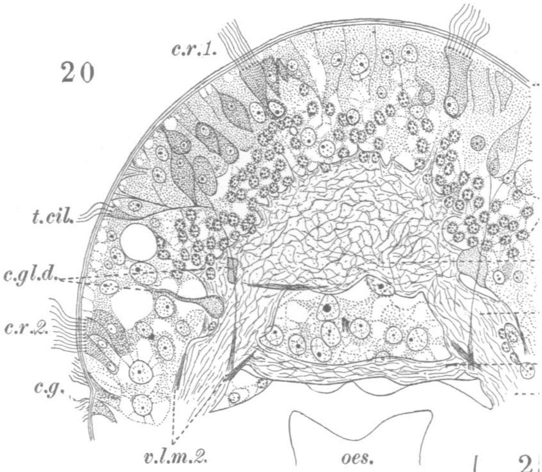

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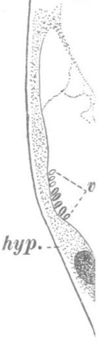

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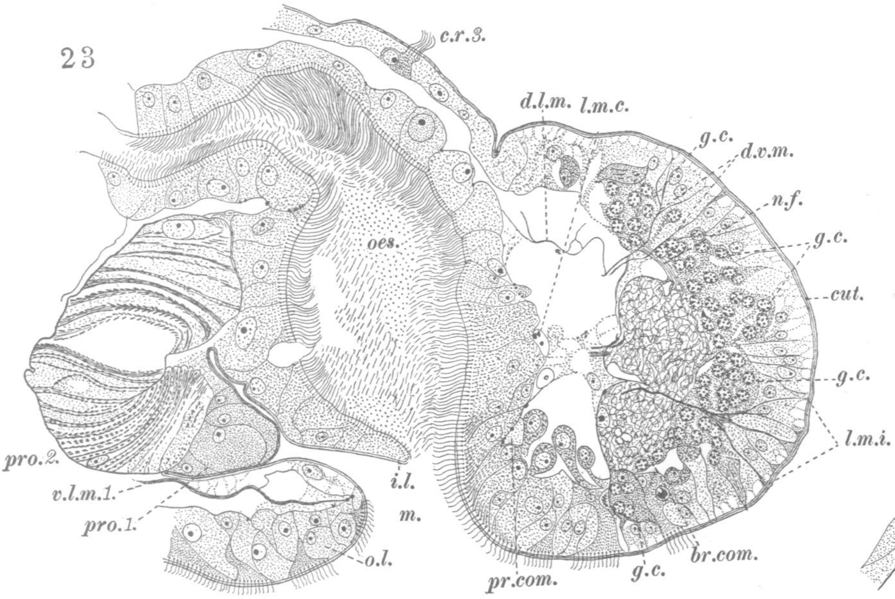

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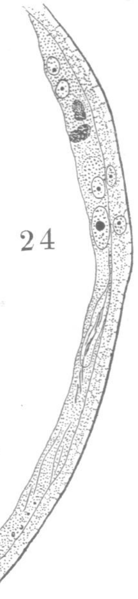

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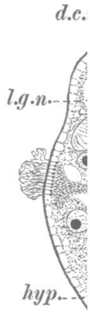

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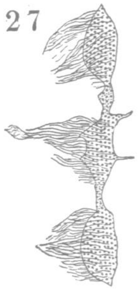

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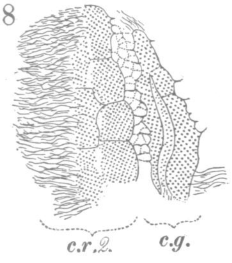

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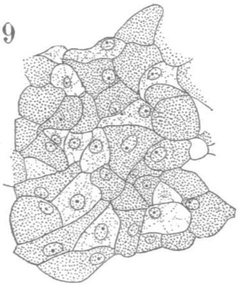

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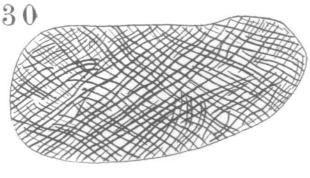

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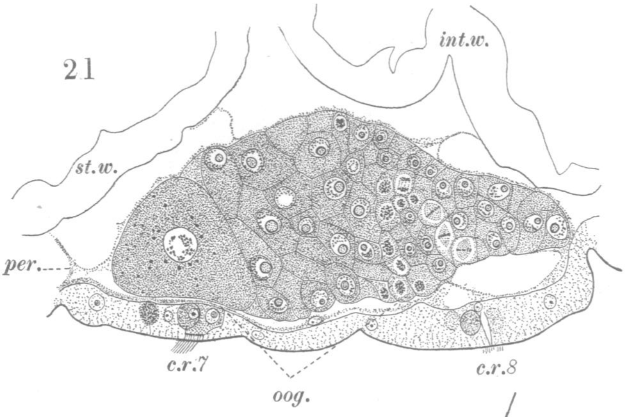
PLATE XIII.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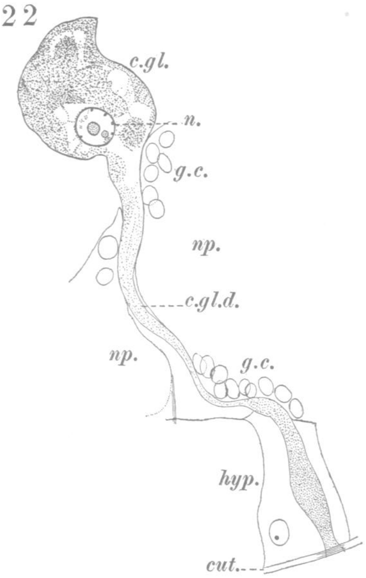
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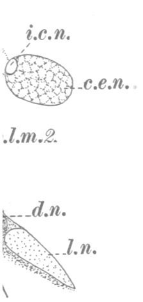
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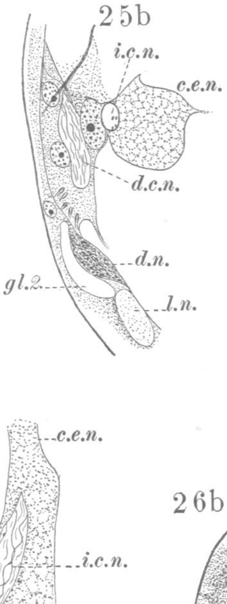
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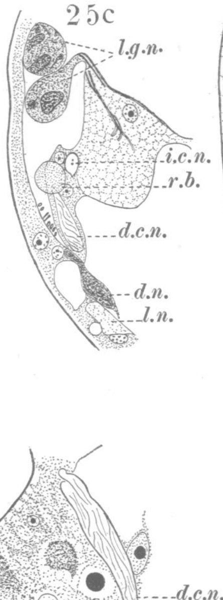
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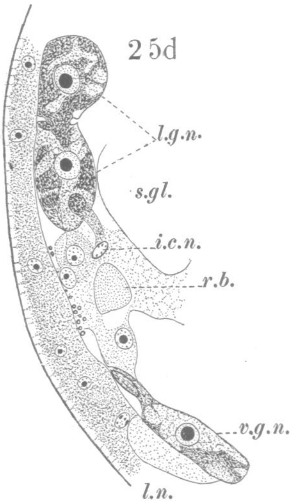
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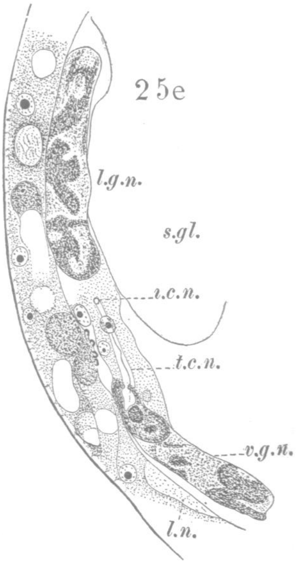
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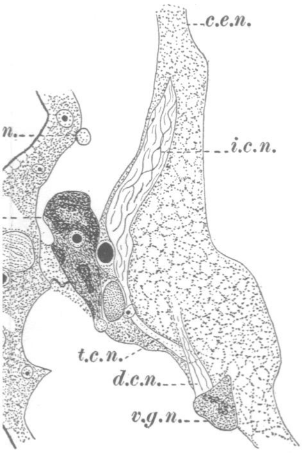

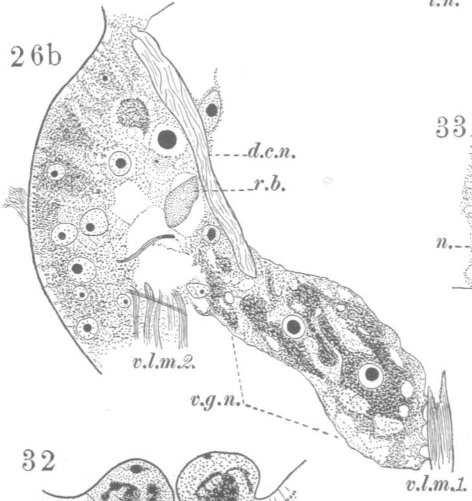
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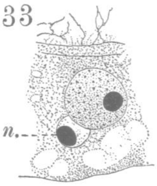
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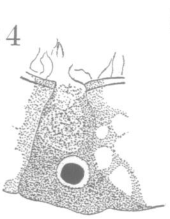
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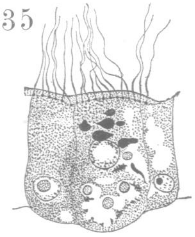
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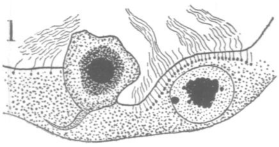
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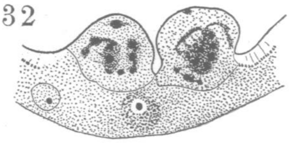
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